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In This Issue:

Self-Sterility in Sugar Cane:

Self-sterility, or the inability of a plant to fertilize itself, may be due to several organic or inherent reasons. (1) Both the male and female germ cells may be non-functionable. Such a condition is often found in hybrids resulting from inter-species crossing. (2) The male germ cells (pollen) alone may be abortive. Such a condition is much more common than the first, where both the male and female organs are non-functionable. (3) Both the male and female germ cells may be normal, but those of the same variety are not capable of functioning on one another. Such a situation is known as self-sterility or self-incompatibility. In plants where this phenomenon has been studied intensively it has been found that the pollen tubes formed from the pollen of the same plant grow so slowly down the style that they do not reach the ovules (female germ cells) while they are still receptive. On the other hand, if pollen of this same variety is dusted on the stigmas of another variety it will grow rapidly down the style and fertilize the ovules.

It is a coincidence that the principal varieties of both the pineapple and sugar cane of these Islands fall in this last category.

A study of the self-sterility or self-fertility of the cane varieties used for breeding is most essential in determining which varieties may be safely used as females in a cross. Canes which have normal male and female germ cells but are known to be self-sterile can be conveniently used as either a male or female (or both) in a cross.

Irrigation Studies—Waipio:

The results of an experiment dealing with the relative efficiency of labor and irrigation water where one line, two lines, and four lines are irrigated as a unit from a single pani, appear in this issue. There is a very significant difference in labor and irrigation water requirement per ton of sugar in the different treatments.

The results indicate that the one-line system is the most efficient, the two-line system is less efficient, but allows time for weeding and stripping, while the four-line system is wasteful of water and labor.

Accumulations of Starch in Natal Uba:

There appears to exist a correlation of juice purity of Natal Uba cane with the pH value of the soil on which it is grown. In this variety of cane, grown on an acid soil, excessive accumulations of starch are found in the stalks which may account for abnormal impurities in the juice. It has been shown by others that such large accumulations of starch do not occur in Natal Uba cane grown on an alkaline soil.

Histological examinations were made for these accumulations of starch in the stalks of Natal Uba grown here in Hawaii on a soil with a pH value of 5.3. These examinations were extended to a number of our Hawaiian varieties also grown on an acid soil.

These examinations demonstrate two types of starch accumulations. The first type occurs, without exception, in the upper part of the stalks of all varieties of cane so far examined. The second type occurs only in Natal Uba and only in the mature portion of the stalks of this cane.

These starch accumulations are interesting, not only because of apparent correlation between them and the reaction of the soil and between them and juice purity, but because they are suggestive of causes of varietal variations in the rooting habits of cane and because they may have a bearing on seed selection.

Varieties at Waipio Substation:

In this issue of the *Record* we report the results of a variety test at Waipio. In this test several canes gave as good or better yields than H 109. These are 25 C 19, 25 C 7, 25 C 4 and 20 S 15.

25 C 19 is a fast grower and a fine sugar producer, but is limited to special districts. It will not do in eye spot areas or where weed control is an important factor. It is also subject to wind damage. 25 C 7 and 25 C 4 are more resistant to eye spot and close in better, but are probably not such heavy producers under ideal conditions.

20 S 15 is to be recommended, on account of its splendid juices. We feel that these four canes deserve trial in final field tests, especially in the irrigated districts.

Uba Hybrids at Honokaa Sugar Company:

The systematic efforts of the Honokaa Sugar Company in testing and retesting the early series of 110 Uba hybrids have been largely responsible for the isolation of the few leaders we now have in this group.

The plant and ratoon harvesting results from a large experiment, which included nearly every seedling of the 1924 Uba hybrid series, are reported in this issue. The results are suggestive as to which seedlings of the group should be pursued in further tests.

The seedlings in this test, which showed substantial gains over the D 1135 check, both in plant and first ratoon yields, are: U D 1, 7, 9, 35, 37, 58, 92, 104 and 110. It is interesting to note that the average quality ratio for all the Uba hybrids was 12.8 per cent better in the first ratoon than in the plant, while the average quality ratio for the D 1135 checks was only 2.5 per cent better.

Variety Tests at Olaa Sugar Company:

We are indebted to Raymond Conant for the article in this number on the results obtained from a variety test at Olaa in which P. O. J. 36 and U. D. 1 distinguished themselves by giving large gains over the standard D 1135 as well as all other competitors.

One of these tests was planted in an upper field and another in a middle belt field, where D 1135 is the standard cane. The canes selected for these tests were K 107, K 202, U. D. 1, P. O. J. 979 and P. O. J. 36.

P. O. J. 36 gave a substantial increase in sugar over D 1135 in both areas. This increase amounted to as much as 108 per cent when compared directly with its adjacent plots in the middle belt field.

U. D. 1 gave a greater increase in sugar over D 1135 in the upper lands, but due to its susceptibility to disease, it is a doubtful commercial cane for the upper levels.

Because of its disease resistance P. O. J. 36 is perhaps the better cane for these Olaa areas.

Other varieties tried out against D 1135 in these tests, viz., K 107, K 202 and P. O. J. 979, gave inferior returns as compared with P. O. J. 36 and U. D. 1.

The details with graphs are given in the complete article on page 310.

Phosphoric Acid and Potash:

In a report of the results of Waipio Experiment V, it is shown that for ten years phosphoric acid and potash were not needed. Then distinct indications of the need for potash were shown.

These field results are confirmed by a soil analysis where the available potash supply is shown to be low.

Colloids and the Caking Quality of Raw Sugars:

A report on an investigation of the relation of colloid phenomena to the hardening tendency of raw sugar by A. L. Holven, of the staff of the Crockett Refinery, appears in this issue. Mr. Holven has not been able to find any definite relation.

This work was requested of the Crockett organization because of facilities at Crockett for studying hardening under controlled relative humidity conditions and also because suitable samples could be selected more readily at the Refinery.

Amounts of the Less Essential Plant Nutrients Present in the New Concentrated Fertilizers:

In recent years a great deal of study has been given to the problem of determining the number of elements which are essential for plant growth. Minute traces of bromine, iodine, copper, manganese, fluorine, boron and zinc have been found to be necessary for the growth of many agricultural plants. In connection with studies that are now being carried on by the chemical department, to determine the value of the less usual nutrients for sugar cane, it appeared desirable to know the amounts of these materials that are being added to the new concentrated fertilizers. All the new concentrated materials were found to contain more manganese, copper and zinc than the older forms of fertilizer materials. None of the new products was found to contain boron or iodine. Fluorine was present in approximately equal amounts in the newer and older forms of phosphates.

The Availability of Potash:

In our soil fertility investigations at Kilauea, the studies on potash availability have yielded results somewhat at variance with our general observations on plantation soils. The soils are very low in citric soluble potassium and while most Island soils respond when such deficiencies are "made up," no such response has been obtained at Kilauea. We have identified the form in which potassium, applied as fertilizer, is fixed by Kilauea soils and shown it to be just as reactive chemically as that in a soil from the Waipio substation except for its lesser solubility in 1 per cent citric acid. Theoretically, from the knowledge we have gained of potassium availability in Kilauea soils, the potash which we have shown to be absorbed by the soil should by all means be available to the crop. There appears to be some "outside" factor interfering with assimilation or it may be that at cooler temperatures the cane has a higher potash requirement. We are continuing our studies along this line.

Soil Acidity:

To those who are associated with the sugar industry of the Islands, the lower productive capacity of the mauka fields has always been evident, and it would seem to the casual observer that the mauka lands present the greater opportunity for improving sugar yields. How much of the lower yield is due to temperature and how much to soil fertility can only be conjectured. The principal difference between mauka and makai lands is the greater acidity of the former. Yet, there is

no outstanding evidence of any greatly improved yields from liming the mauka fields to correct this acidity. It is true that in some cases a response to liming has been obtained, but then, again, there are plenty of instances where no response or even injury has resulted.

Our knowledge of the nature and the properties of the compounds causing soil acidity has been greatly clarified during the last few years, and we are now better prepared to interpret the effects of lime on mauka lands.

The soils of Kilauea Plantation are, with few exceptions, acid soils, and also their fertility is low. Then, again, variable effects from liming these soils have been noted, so conditions there are well suited for a study of the influence of lime on the fertility of our acid soils. We have completed a rather extensive study of the nature of the acidity in our soils, the extent to which the bases have been displaced by the soil acidity, and the total capacity which the soils have for fixing bases, which is presented in this number of the *Record*. A number of very significant observations have been made, which adds greatly to our fundamental knowledge of our acid soil types.

Electrodialysis of Hawaiian Soils:

This is a companion article to the report appearing in this issue entitled "Availability of Potash." The manner of determining potash by electrodialysis is discussed, and a description is given of the apparatus employed. The effect of electrodialysis upon a series of Hawaiian soils was studied in some detail. The results obtained were especially considered in regard to the study of potash availability at Kilauea, Kauai.

Some Chemical Reminiscences:

We present in this issue an address delivered by Dr. L. L. Van Slyke at a recent meeting of the Hawaiian Section of the American Chemical Society. Dr. Van Slyke was a pioneer teacher of chemistry in Hawaii. The picture he draws of conditions then existing, is in striking contrast to the close affiliation of science and industry in Hawaii today.

Dr. Van Slyke has been in charge of chemical research at the New York State Agricultural Experiment Station for many years. His investigations have contributed much to our knowledge of the chemistry of milk and dairy products and he has earned an enviable reputation as an authority on this subject.

Self-Sterility in Sugar Cane

By A. J. MANGELSDORF and C. G. LENNOX

The failure of a plant to fertilize itself may result from a number of causes. Environmental effects, such as excessive heat or cold, too much or too little moisture, soil toxicity, and so on, may cause failure in seed setting. We are not concerned here with environmental effects like those just mentioned. Only those causes inherent in the plant itself are under consideration. Some of these will be briefly discussed.

1. Failure to develop either viable pollen or viable ovules is a common cause of infertility. Sterility in both sexes often occurs in the offspring of wide crosses. In the animal kingdom the mule is the classical example. The offspring of crosses between different species of sugar cane also tend to be sterile in both sexes. P. O. J. 36, a cane which is rapidly gaining favor in Hawaii, is a cross between *Saccharum officinarum*, variety Striped Mexican, and *Saccharum barberi*, variety Chunnee. Both its ovules and its pollen have proved thus far to be completely sterile.

2. Because of abortive pollen, many plants are unable to fertilize themselves, even though their ovules are functional. This category includes a considerable number of our important canes, among them Lahaina, Tip and Uba. This condition may possibly have had as its cause wide crossing somewhere in the ancestry of the plant. The male germ cells of both plants and animals are much more likely to be abortive as a result of irregularities in reduction division than are the female germ cells. For this reason male sterility as a result of wide crossing is much more common than female sterility. Whenever the pollen of a plant is fertile one may be quite certain of female fertility, except, of course, in the case of dioecious plants. The converse, however, does not hold.

3. The last category to be mentioned, and the one which forms the subject of this paper is self-sterility or self-incompatibility. Here both ovules and pollen are viable, as evidenced by the fact that they function normally when used in crosses with other individuals. The pollen of a given plant, however, is unable to fertilize the ovules of that plant even when dusted on the stigmas in abundance.

Self-sterility is not a rare phenomenon in the plant kingdom. Examples are known in over a hundred different species, representing some thirty-five families. Certain kinds of plums, cherries, and clover are familiar examples of self-sterility.

It is a coincidence that the two principal crops in these Islands, pineapples and sugar cane, are both self-sterile to a high degree. We are informed by members of the Pineapple Station staff that the stigmas of a Cayenne pineapple plant may be covered with pollen from any other Cayenne plant without effect. No seed setting results. All Cayenne plants are, of course, in reality, merely parts of a single plant. Pollinated with pollen from a different pineapple variety, such as Queen, for example, the Cayenne sets seed freely. We have to thank the phenomenon of self-sterility for the absence of seeds in our sliced pineapple.

The situation is similar in H 109. The stigmas of an H 109 tassel covered with its own pollen, or with the pollen from any other H 109 tassel, fail to set seed. Pollinated with pollen from another variety, say D 1135, it sets seed abundantly.

The cause of self-sterility in certain other self-sterile plants in which the phenomenon has been studied intensively, has been found to lie in the fact that the pollen tubes grow very slowly down the styles of the plant which produced them; too slowly, in fact, to reach the ovules while they are still receptive. The same sort of pollen grains, however, applied to the stigmas of another variety, send their tubes down the style with great rapidity and fertilize the ovules within a day or two.

It must be mentioned that in both Cayenne pineapple and H 109 cane the setting of seed in the absence of other varieties does occur, though rarely. The reasons for these occasional exceptions are not known.

H 109 has been cited as an example of almost complete self-sterility. Not all varieties are so highly self-sterile. Indeed, among the canes producing an abundance of pollen there are many gradations between the extreme self-sterility of H 109 on the one hand and the complete self-fertility of H 456 on the other. The following table classifies the varieties thus far studied according to their self-sterility:

RELATIVE SELF-STERILITY OF CERTAIN CANES PRODUCING AN ABUNDANCE OF POLLEN

Classification Based on Preliminary Results and Subject to Revision

A. Partially or Completely Self-Sterile.

| | | | |
|--------|---------|------------|--------|
| H 109 | 26 C 48 | Paia F | 25 C 4 |
| H 8965 | D 117 | Makaweli 3 | 25 C 7 |
| H 5909 | D 1135 | Wailuku 2 | |
| H 9811 | 20 S 16 | K 202 | |
| Badila | 20 S 17 | 26 C 189 | |

(Many others have, to date, given no seedlings on selfing, but must be tested further before their self-sterility can be regarded as definitely established.)

B. Partially or Completely Self-Fertile.

| | | | |
|---------|-----------|-----------|--------|
| H 456 | Wailuku 4 | U. S. 666 | H 7102 |
| H 27 | 26 C 113 | K 73 | H 472 |
| H 9909 | 26 C 148 | K 107 | |
| H 8906 | 26 C 270 | 25 C 14 | |
| H 86484 | 27 C 514 | Cavengire | |

It is desirable that the degree of self-fertility of all of the more important cane varieties be determined, for practical reasons. If a variety produces a reasonable amount of pollen and is nevertheless self-sterile it may be used either as a male or as a female (or both) in crosses. When two pollen-producing self-sterile varieties are crossed together, each variety will function both as a male and as a female in the cross. The fuzz from both varieties may therefore be planted with full assurance that the resulting seedlings are the result of crossing. The number of tassels required to produce a given number of seedlings may, therefore, be

halved by planting the fuzz from both participants in the cross. Since emasculation is not practicable in sugar cane, a variety which produces pollen may be safely used as a female parent only after the degree of its self-sterility has been determined. If it is relatively self-fertile, too many of its seedlings are likely to be the result of self-pollination, and these are usually worthless except for breeding purposes.

The determination of the degree of self-sterility of a given variety is rather easily accomplished. The procedure consists merely in isolating from possible contamination by foreign pollen a few tassels of the variety in question, taking care to see that all open flowers are first removed.

The relative degree of self-sterility is judged from the number of seedlings obtained. Highly self-sterile varieties, like H 109 or Badila, seldom yield upon selfing more than a half dozen seedlings per tassel, while a self-fertile variety, like H 456, may produce a thousand or more.

Since environmental influences may also result in failure to set seed, the trials on a given variety should be repeated over several seasons, and with tassels from as many different sources as possible, before final conclusions are drawn as to the degree of self-sterility.

SUMMARY

1. Many varieties of sugar cane have sterile pollen and some have sterile ovules. This condition in other plants, and probably in sugar cane as well, results most commonly from wide crossing in the recent ancestry of the plant.
2. Of the varieties of cane having fertile pollen and ovules, a large proportion are more or less self-sterile. Self-sterility has been found in other plants to be due to the failure of the pollen tubes to grow rapidly enough down their own styles to accomplish fertilization before the flower withers.
3. Information as to the degree of self-sterility of the canes intended for breeding is useful in planning crosses between them.

Irrigation Studies—Waipio

COMPARISON OF ONE-LINE, TWO-LINE AND FOUR-LINE IRRIGATIONS

By F. C. DENISON and H. R. SHAW

The relative efficiency in labor and water of irrigating one line at a time, two lines as a "U", or four lines zigzag was tested in watercourse plots on H 109 cane, second ratoons, 20 months old. The plots were approximately 0.2 acre in size, and were in series with five replications of the one-line treatment and four replications each of the two-line and four-line treatments. Water was measured

by Great Western meters at the junction of each watercourse and the level ditch; hence all water figures given are *net* water. A record of water used and hours labor required for each plot was carefully maintained. All irrigations were made by one man in order to eliminate the variation between individuals. The irrigator was allowed to follow the usual practice, no extra instructions or supervision being given.

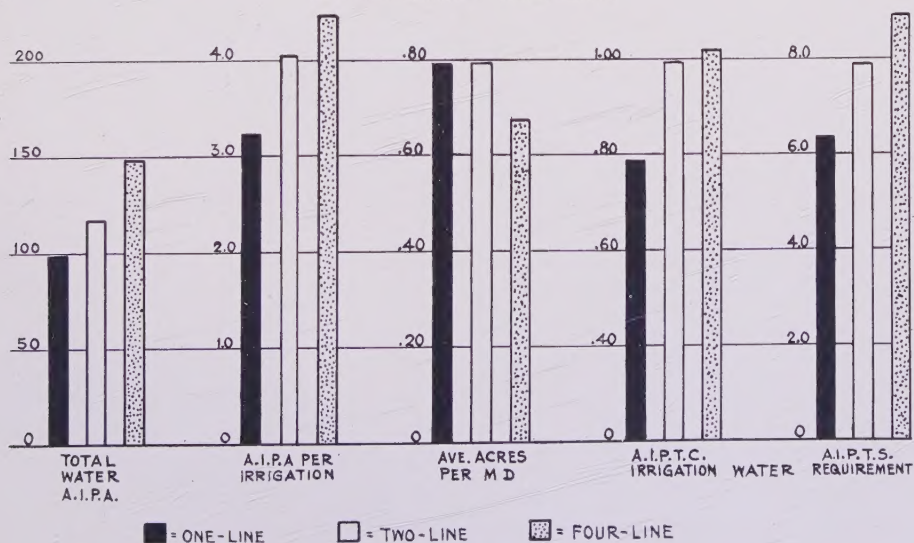
An examination of the results from each watercourse shows little variation in yield, either in cane or sugar. It should be pointed out, however, that such would probably not be the case on land with any considerable slope. The erosive effect of allowing water to cut down the watercourse for four lines or more would undoubtedly lower the yield figures. On level land such a consideration does not enter to as great an extent.

There is a very significant variation in water and labor requirements for the different treatments. The one-line irrigation shows a considerable saving in water, using a total of 70.69 acre inches as against 89.41 acre inches in the two-line system and 98.66 acre inches in the four-line. In the average application per irrigation throughout the crop, the two-line system required over 26 per cent, and the four-line system over 40 per cent more water than the one-line irrigation.

There is relatively little difference in labor requirement indicated by the results from the one-line and the two-line systems. The four-line plots, however, required nearly 15 per cent more labor for each irrigation than the other two treatments.

The most significant basis of comparison is on the irrigation water requirement per ton of sugar. Here, the two-line method demands 25 per cent and the four-line system 40 per cent more than the one-line method.

COMPARISON OF ONE-LINE, TWO-LINE
AND FOUR-LINE IRRIGATION
WAIPIO SUBSTATION EXP. P, 1929 CROP
H 109 - 2nd-RATOONS 20 MONTHS OLD



CONCLUSIONS

1. The system of irrigating one line at a time appears to be most efficient in saving labor and water.

2. Results indicate that the two-line "U" system is less efficient than the one-line. In localities where labor and not water is the limiting factor, it is possible that the two-line system may prove more satisfactory. The fact that half the number of *panis* are required and that the longer time required to fill two lines instead of one gives the irrigator an opportunity to weed and strip the watercourse, may make this system more economical.

3. The custom of cutting four or more lines in the watercourse is highly inefficient. It requires a longer length of time for irrigation, is wasteful of water, and gives an uneven distribution of water to the cane. The fact that one irrigator may handle two or three watercourses at one time with this system does not equalize the disadvantage of waste, unequal distribution, and poor condition of the lines due to flooding the upper furrows and improper control of water.

(See accompanying diagram.)

EXPERIMENT P

Object: To compare the number of lines irrigated as a unit from a single *pani*, i. e., one line, two lines, and four lines.

Crop: H 109 second ratoons long, 20 months old when harvested.

Layout: Thirteen watercourse plots about 0.2 acre each. Each watercourse water measured by Great Western meter.

Fertilization: Uniform to all plots:

| Aug., 1927 | Oct., 1927 | Feb., 1928 | Total | | |
|------------|------------|------------|-------|-------------------------------|------------------|
| | | | N | P ₂ O ₅ | K ₂ O |
| 1000 C. F. | 488 A. S. | 561 A. S. | 300 | 80 | 80 |

Summary of Results

| Plots | No. of Plots | Treatment | T. C. P. A. | Q. R. | T. S. P. A. | Total Acre |
|-------|--------------|-----------------------|-------------|-------|-------------|-----------------|
| | | | | | | Inches per Acre |
| A | 5 | One line | 88.96 | 8.02 | 11.09 | 98.76 |
| B | 4 | Two-line units | 90.13 | 7.99 | 11.29 | 117.60 |
| C | 4 | Four-line units | 89.71 | 8.16 | 11.01 | 126.64 |

EXPERIMENT P
DETAILED WATERCOURSE RESULTS

| Plot..... | Area..... | Total T. C..... | T. C. P.A..... | Q. R..... | T. S. P. A..... | Brix..... | Polarization..... | Purity..... | No. of Irrigations..... | Total Acre Inches..... | Average for Crop Acre Inches per Acre..... | Rain Acre Inches per Acre..... | Irrigation Acre Inches per Acre..... | Man Days..... | Acres per Man Day..... | Water Requirement Only | | Total Water | |
|-------------------|-----------|-----------------|----------------|-----------|-----------------|-----------|-------------------|-------------|----------------------------|---------------------------|--|-----------------------------------|---|---------------|---------------------------|-----------------------------------|----------------------------------|-----------------------------------|----------------------------------|
| | | | | | | | | | | | | | | | | Acre Inches per Ton Sugar..... | Acre Inches per Ton Cane..... | Acre Inches per Ton Sugar..... | Acre Inches per Ton Cane..... |
| 1A | .2116 | 19,128 | 90.40 | 7.50 | 12.05 | 19.62 | 17.46 | 89.3 | 24 | 81.26 | 2.22 | 27.89 | 53.37 | 7.60 | 0.668 | 4.43 | 0.59 | 4.43 | 6.74 |
| 4A | .2246 | 20,748 | 92.38 | 8.30 | 11.13 | 18.80 | 16.33 | 86.7 | 24 | 99.08 | 2.95 | 28.19 | 70.89 | 6.35 | 0.849 | 6.37 | 0.77 | 6.37 | 8.90 |
| 7A | .2201 | 19,2775 | 87.59 | 8.08 | 10.84 | 18.90 | 16.46 | 87.1 | 21 | 105.90 | 3.71 | 27.95 | 77.95 | 4.95 | 0.934 | 7.19 | 0.89 | 7.19 | 9.77 |
| 10A | .2088 | 17,7825 | 85.17 | 7.97 | 10.69 | 19.18 | 16.69 | 87.0 | 23 | 96.30 | 2.98 | 27.87 | 68.43 | 6.15 | 0.781 | 6.40 | 0.80 | 6.40 | 9.01 |
| 13A | .2556 | 22,7625 | 89.06 | 8.23 | 10.82 | 19.27 | 16.36 | 85.0 | 21 | 111.25 | 3.94 | 28.46 | 82.79 | 6.10 | 0.880 | 7.65 | 0.93 | 7.65 | 10.28 |
| Average A Plots.. | .11207 | 99,6985 | 88.96 | 8.02 | 11.09 | 19.15 | 16.66 | 87.0 | 22 | 98.76 | 3.21 | 28.07 | 70.69 | 6.23 | 0.792 | 6.37 | 0.79 | 6.37 | 8.90 |
| 2B | .2309 | 20,103 | 87.06 | 7.74 | 11.25 | 19.08 | 16.96 | 89.0 | 22 | 97.93 | 3.17 | 28.19 | 69.74 | 6.25 | 0.813 | 6.20 | 0.80 | 6.20 | 1.12 |
| 5B | .2389 | 22,120 | 92.59 | 8.00 | 11.37 | 19.10 | 16.73 | 87.4 | 23 | 132.68 | 4.54 | 28.19 | 104.49 | 6.75 | 0.814 | 1.13 | 0.93 | 1.13 | 8.90 |
| 8B | .2138 | 19,880 | 92.98 | 8.03 | 11.58 | 18.80 | 16.49 | 87.8 | 23 | 108.08 | 3.65 | 27.89 | 80.19 | 6.05 | 0.777 | 0.86 | 0.86 | 0.86 | 1.47 |
| 11B | .2505 | 22,0875 | 88.17 | 8.18 | 10.78 | 18.83 | 16.33 | 86.5 | 22 | 131.69 | 4.69 | 28.48 | 103.21 | 6.75 | 0.816 | 1.17 | 0.97 | 1.17 | 9.33 |
| Average B Plots.. | .9341 | 84,1905 | 90.13 | 7.99 | 11.29 | 18.95 | 16.63 | 87.68 | 22 | 117.60 | 4.06 | 28.19 | 89.41 | 6.45 | 0.746 | 0.99 | 0.99 | 0.99 | 1.43 |
| 3C | .2175 | 20,555 | 94.51 | 8.01 | 11.80 | 18.64 | 16.53 | 88.8 | 22 | 128.47 | 4.57 | 27.89 | 100.58 | 7.65 | 0.825 | 1.06 | 0.852 | 1.06 | 10.88 |
| 6C | .2312 | 20,6175 | 89.25 | 7.98 | 11.18 | 19.35 | 16.68 | 86.5 | 22 | 123.65 | 4.35 | 27.95 | 95.70 | 7.35 | 0.692 | 1.07 | 0.858 | 1.07 | 11.06 |
| 9C | .2226 | 20,3425 | 91.39 | 8.26 | 11.06 | 18.70 | 15.66 | 86.4 | 22 | 128.27 | 4.56 | 27.89 | 100.38 | 7.35 | 0.666 | 1.10 | 0.908 | 1.10 | 11.60 |
| 12C | .2431 | 20,5125 | 84.38 | 8.43 | 10.01 | 18.37 | 15.86 | 86.4 | 22 | 126.20 | 4.48 | 28.98 | 98.66 | 7.51 | 0.669 | 1.10 | 0.896 | 1.10 | 11.50 |
| Average C Plots.. | .9144 | 82,0275 | 89.71 | 8.16 | 11.01 | 18.76 | 16.18 | 87.0 | 22 | 126.64 | 4.45 | 28.21 | 98.99 | 7.70 | 0.693 | 1.16 | 0.979 | 1.16 | 12.61 |

Accumulations of Starch in the Stalks of Natal Uba Cane Grown on Acid Soil

By D. M. WELLER

At the annual conference of the Cuban Sugar Technologists in 1928, J. Alfaro of Palmira pointed out an interesting correlation of juice purity of Natal Uba cane with the pH value of the soil on which it was grown. E. Haddon, chemist, Incomati S. E., Ltd., Xinavane, Portuguese East Africa, had previously pointed out that in Uba cane (Natal) grown on acid soil there were accumulations of starch, while in that grown on alkaline soils there were not. Mr. Alfaro writes in the *Proceedings of the Second Annual Conference of the Association of Sugar Technologists of Cuba*:



Fig. 1. Longitudinal section of stalk of H 109 cane showing accumulations of starch in the cells adjacent to the vascular bundles. This section was taken from the region of the stalk immediately above the node subtended by a functioning leaf. The pH value of the soil on which this cane was grown was 5.3. (X140)

However, in August, 1927, the publication *Sugar* published a resume of a work which Mr. Haddon had in turn published, in the *Revue Agricole de Maurice*, in which he came to the conclusion that the Uba cane grown there on acid soil produced considerable quantities of starch, while on alkaline soils there were no indications of it, attributing to the starch the principal cause of the impurities in the juice of the Uba cane. This observation of Mr. Haddon was also later confirmed by Feuilherade, according to *Sugar* in the January issue of the present year (1928), as well as by de Sornay, according to the *International Sugar Journal* of the month of November, 1927.

In view of these facts some histological examinations were made for the accumulations of starch in the stalks of Natal Uba grown here in Hawaii on a soil with a pH value of 5.3. These examinations were extended to a number of our Hawaiian varieties also grown on an acid soil with a pH value of 5.3. These tests were made by cutting microtome sections from pieces of the stalk, treating them with iodine solution, and studying them under the microscope. These pieces of the stalk were taken from the region immediately below the node, from the nodal region, and from the region immediately above the node. In each case the node selected was one high enough on the stalk to be subtended by a functioning leaf. A test was considered positive when there was an accumulation of starch grains within the parenchyma cells, such as is pictured in Figs. 1 and 2. When the tissue was perfectly clear showing no starch grains whatsoever the test was called negative.

The results of such tests on several varieties of cane are shown in Table I:

TABLE I

Showing the results of tests for the accumulation of starch in the stalks of several varieties of cane grown on a soil with a pH value of 5.3. Each node was from a region high enough on the stalk to be subtended by a functioning leaf. A minus sign indicates that the test was negative and a plus sign that it was positive.

| Variety | Below Node | Node | Above Node |
|---------------------|------------|------|------------|
| H 109 | — | — | + |
| H 109* | — | — | + |
| Hawaiian Uba | — | — | + |
| Natal Uba | — | — | + |
| Porto Rico Uba..... | — | — | + |
| D 1135 | — | — | + |
| U. D. 1..... | — | — | + |
| P. O. J. 36..... | — | — | + |

From the data shown in Table I it is seen that, for a node subtended by a leaf, in no case was there an accumulation of starch grains, either below or in the node itself, but that without exception there was an accumulation of starch above the node. This was true for H 109 canes which were grown on soils with pH values of 5.3 and 7.5.

In the same way these tests were made using nodes from a different region of the same stalks. These nodes were selected so that each one was about two

* Grown on a soil with a pH value of 7.5.



Fig. 2. Longitudinal section of the stalk of H 109 cane at the same region as that of Fig. 1. (X745)

feet below the lowest functioning leaf of that stalk. The results of these tests are shown in Table II:

TABLE II

Showing the results of tests for the accumulation of starch in the stalks of several varieties of cane grown on a soil with a pH value of 5.3. Each node was taken from the mature portion of the stalk about two feet below the lowest functioning leaf. A minus sign indicates that the test was negative and a plus sign indicates that it was positive.

| Variety | Below Node | Node | Above Node |
|---------------------|------------|------|------------|
| H 109 | — | — | + |
| H 109* | — | — | + |
| Hawaiian Uba | — | — | — |
| Natal Uba | + | + | + |
| Porto Rico Uba..... | — | — | — |
| D 1135 | — | — | + |
| U. D. 1..... | — | — | + |
| P. O. J. 36..... | — | — | — |

* Grown on a soil with a pH value of 7.5.

From the data shown in Table II it is seen that for the varieties H 109, D 1135, and U. D. 1 the same results were obtained for nodes of the mature part of the stalk as for those subtended by a functioning leaf, i. e., accumulation of starch occurred neither below nor in the node, but in the tissue above the node. For the Hawaiian Uba, the Porto Rico Uba, and the P. O. J. 36 there was no accumulation below the node, in the node, or above the node. *The Natal Uba showed accumulations in all three places.*

It is to be noted that all accumulations of the starch grains in the tissue above the nodes subtended by leaves occurred in the parenchyma cells adjacent to the vascular bundles. In several instances as many as three rows of cells surrounding the bundles showed these accumulations (Figs. 1 and 2). This was true also of accumulations in the tissue above the nodes taken from a point on the stalk about two feet below the lowest functioning leaf for all of those varieties where accumulations occurred, *except that of Natal Uba*. In this variety a marked difference

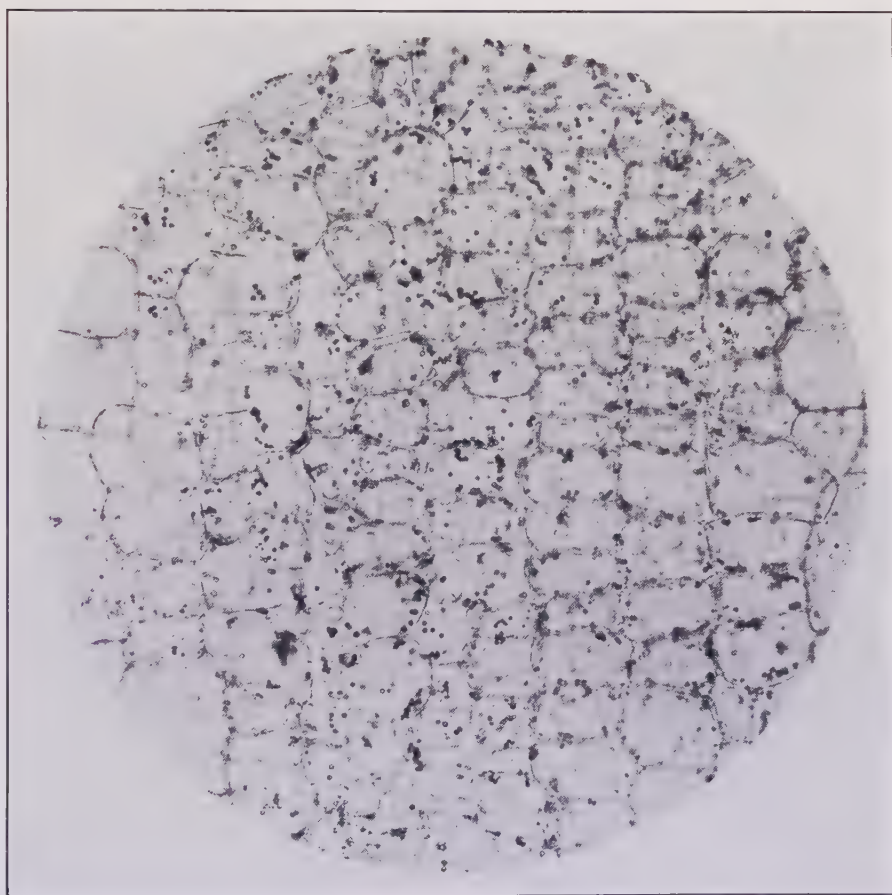


Fig. 3. Longitudinal section of Natal Uba cane showing accumulations of starch grains in all of the parenchyma cells, both in those adjacent to the vascular bundles and in those lying between the bundles. This section was taken from the region of the stalk immediately below a node. The pH value of the soil on which this cane was grown was 5.3. (X140)

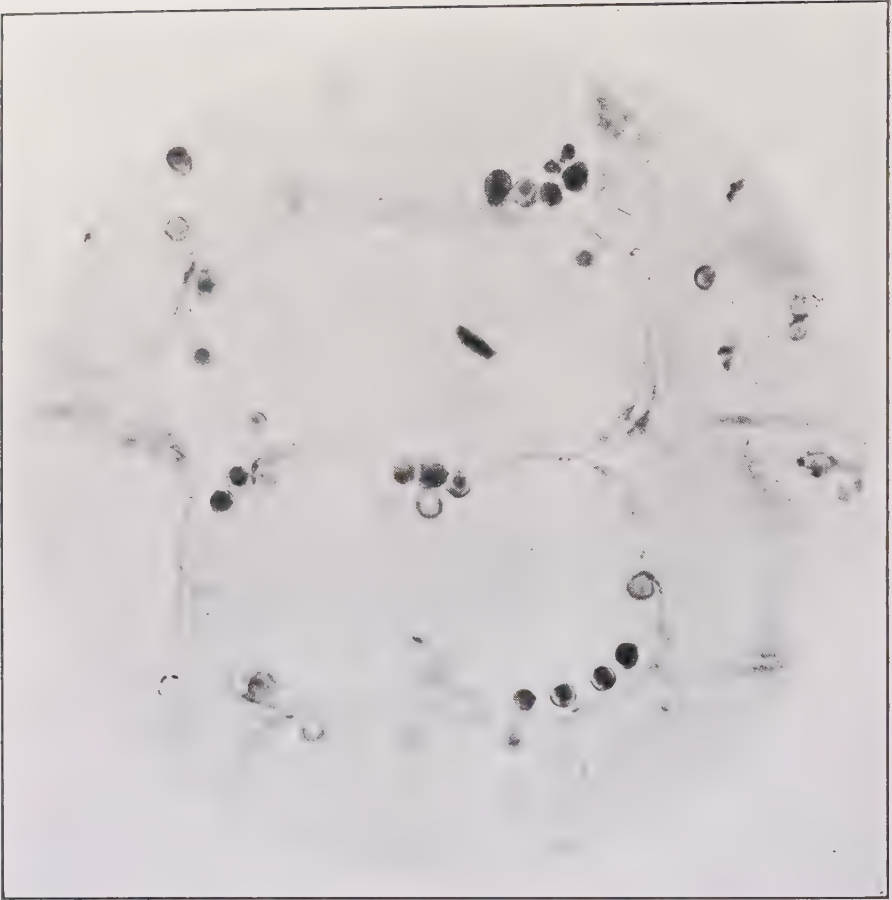


Fig. 4. Longitudinal section of the stalk of Natal Uba cane at the same region as that of Fig. 3. (X745)

was noted in that such accumulations occurred in all of the parenchyma cells, both in those adjacent to the vascular bundles and in those lying between the bundles. (Figs. 3 and 4.)

Dr. A. J. Mangelsdorf is growing Natal and Hawaiian Uba cane in large concrete tubs, using a neutral soil (pH value of 7.5) and the same soil with pH values adjusted to 5.3 and 8.5. In the same way as described above, tests for the accumulations of starch will be made on the stalks of these canes grown in soils with three different pH values. If the pH value of the soil is the direct or indirect cause of these accumulations of starch, these tests should show marked differences in the accumulations.

There are, then, two distinct types of these starch accumulations in the cane plant. The first type occurs only *above the nodes* in the first two or three layers of parenchyma cells surrounding the vascular bundles.

The second type occurs in all of the parenchyma cells, both in those immediately adjacent to the bundles and in all of those cells lying between the bundles.

The first type occurs without exception in all varieties of cane so far examined in the region of the stalk subtended by functioning leaves. This was true for H 109 grown on both an acid and an alkaline soil. This type occurs also in the mature portions of H 109, D 1135 and U. D. 1.

The second type occurs only in Natal Uba cane and only in the mature portions of the stalks of this cane. In this case such accumulations occur not only above the node but below the node and in the node as well. In the young portions of the stalks of this cane, i. e., in those subtended by functioning leaves, the accumulations are, as was pointed out above, of the first type.

In the mature portions of the stalks of Hawaiian Uba, Porto Rico Uba, and P. O. J. 36 there were no accumulations of either type.

These starch accumulations are interesting, not only because of whatever correlation exists between them and the reaction of the soil and between them and juice purity, but because they suggest other correlations.

It has been shown (1, 2) that the shoots of roses grow much more rapidly and develop a much larger and more vigorous root system if the nodes of the cuttings from which they grew showed starch accumulations. These facts are suggestive of causes of varietal variation in the rooting habits of cane and may have a bearing on seed selection.

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Cane Varieties at Waipio Substation

WAIPIO EXPERIMENT S

By J. A. VERRET

The cane in this test was planted in September, 1927, and harvested in March, 1929. Better yields would have been obtained had it been possible to hold the field over two or three months longer.

In the layout every other plot was planted to H 109. All plots received uniform treatment.

The results obtained are summarized:

| Variety | No. of Plots | Tons per Acre | | | Per Cent Gain or Loss in Sugar |
|-------------------|--------------|---------------|-------|-------|-----------------------------------|
| | | Cane | Q. R. | Sugar | |
| 25 C 4..... | 3 | 77.4 | 8.3 | 9.3 | + 15 |
| H 109 checks..... | 6 | 74.9 | 9.2 | 8.1 | |
| 25 C 7..... | 3 | 82.9 | 9.2 | 9.0 | + 11 |
| H 109 checks..... | 9 | 73.3 | 9.1 | 8.1 | |
| 25 C 19..... | 3 | 76.4 | 7.6 | 10.0 | + 22 |
| H 109 checks..... | 9 | 70.0 | 8.5 | 8.2 | |
| 25 C 32..... | 3 | 58.8 | 7.3 | 8.0 | — 4 |
| H 109 checks..... | 9 | 68.9 | 8.3 | 8.3 | |
| 25 C 34..... | 3 | 59.2 | 9.3 | 6.4 | — 28 |
| H 109 checks..... | 9 | 69.3 | 7.8 | 8.9 | |
| 20 S 15..... | 3 | 67.8 | 7.0 | 9.7 | + 7 |
| H 109 checks..... | 9 | 69.8 | 7.7 | 9.1 | |
| 20 S 17..... | 3 | 60.3 | 8.1 | 7.4 | — 21 |
| H 109 checks..... | 9 | 71.4 | 7.6 | 9.4 | |
| 20 S 18..... | 3 | 73.8 | 8.9 | 8.2 | — 7 |
| H 109 checks..... | 9 | 68.6 | 7.8 | 8.8 | |
| 20 S 19..... | 3 | 50.2 | 7.8 | 6.4 | — 27 |
| H 109 checks..... | 6 | 68.6 | 7.8 | 8.8 | |

VARIETY TEST
WAIPIO SUBSTATION EXP. S, 1929 CROP
PLANT CANE 18 MONTHS OLD

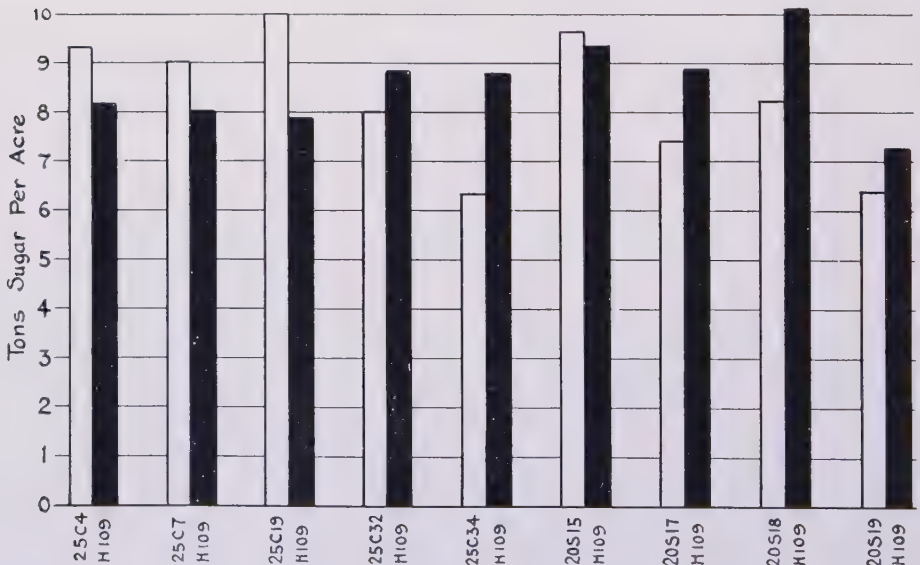


Fig. 1

Several of the above canes give indications of being able to compete with H 109 in certain areas. (See Fig. 1.)

In this test at Waipio 25 C 19 was the most consistent performer. In all cases it produced more cane and sugar than any adjoining H 109 plots. As we had nine H 109 plots adjoining the 25 C 19 these results can be regarded as being significant.

A summary of the reports on agricultural qualities of this cane shows seven cases where it is superior to H 109, nine where it is equal and one where it is inferior. In regard to Yellow Caledonia four of the reports show superiority and three equality. Reports from D 1135 areas show one superior and one inferior observation. In Tip regions it is reported on a par with Tip once, and inferior once.

In the wet districts it seems to have somewhat poorer juices; its susceptibility to eye spot and its open habits of growth do not recommend it for these districts.

VARIETY TEST

WAIPIO SUBSTATION EXP. S, 1929 CROP

PLANT CANE 18 MONTHS OLD.

| | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | Plot No. |
|----------|-------|-------|-------|-------|-------|-------|-------|------|------|----------|
| Div. No. | 20519 | H109 | 20517 | H109 | 25C34 | H109 | 25C19 | H109 | 25C4 | Variety |
| 1 | 50.6 | 81.5 | 57.7 | 70.7 | 58.2 | 70.5 | 81.8 | 70.3 | 78.1 | Cane |
| | 7.83 | 7.62 | 8.13 | 7.30 | 9.33 | 7.90 | 7.64 | 8.8 | 8.3 | Q.R. |
| | 6.5 | 10.7 | 7.1 | 9.7 | 6.2 | 8.9 | 10.7 | 8.0 | 9.4 | Sugar |
| | H109 | 20518 | H109 | 20515 | H109 | 25C32 | H109 | 25C7 | H109 | |
| 2 | 61.7 | 70.0 | 71.1 | 67.8 | 69.7 | 55.7 | 67.9 | 81.5 | 74.1 | |
| | 8.05 | 8.98 | 7.74 | 7.02 | 8.05 | 7.33 | 8.84 | 9.2 | 9.7 | |
| | 7.7 | 7.8 | 9.2 | 9.7 | 8.7 | 7.6 | 7.7 | 8.9 | 7.6 | |
| 3 | 20519 | H109 | 20517 | H109 | 25C34 | H109 | 25C19 | H109 | 25C4 | |
| | 53.0 | 84.1 | 62.7 | 73.6 | 63.8 | 70.6 | 74.0 | 69.6 | 74.2 | |
| | 7.83 | 7.62 | 8.13 | 7.30 | 9.33 | 7.90 | 7.64 | 8.8 | 8.3 | |
| | 6.8 | 11.0 | 7.7 | 10.1 | 6.8 | 8.9 | 9.7 | 7.9 | 8.9 | |
| 4 | H109 | 20518 | H109 | 20515 | H109 | 25C32 | H109 | 25C7 | H109 | |
| | 67.6 | 77.1 | 68.5 | 67.7 | 72.3 | 61.5 | 73.5 | 80.4 | 83.0 | |
| | 8.05 | 8.98 | 7.74 | 7.02 | 8.05 | 7.33 | 8.84 | 9.2 | 9.7 | |
| | 8.4 | 8.6 | 8.9 | 9.6 | 9.0 | 8.4 | 8.3 | 8.7 | 8.6 | |
| 5 | 20519 | H109 | 20517 | H109 | 25C34 | H109 | 25C19 | H109 | 25C4 | |
| | 46.6 | 65.6 | 60.6 | 60.5 | 55.5 | 65.7 | 73.3 | 72.0 | 80.2 | |
| | 7.83 | 7.62 | 8.13 | 7.30 | 9.33 | 7.90 | 7.64 | 8.8 | 8.3 | |
| | 6.0 | 8.6 | 7.5 | 8.3 | 5.9 | 8.3 | 9.6 | 8.2 | 9.7 | |
| 6 | H109 | 20518 | H109 | 20515 | H109 | 25C32 | H109 | 25C7 | H109 | |
| | 50.8 | 74.1 | 66.9 | 67.8 | 70.5 | 59.2 | 68.0 | 86.9 | 80.9 | |
| | 8.05 | 8.98 | 7.74 | 7.02 | 8.05 | 7.33 | 8.84 | 9.2 | 9.7 | |
| | 6.3 | 8.3 | 8.6 | 9.7 | 8.8 | 8.1 | 7.7 | 9.4 | 8.3 | |

Fig. 2

In the dry districts its juices are as good or better than H 109.

In the limited areas to which it is adapted we feel that in most cases it will outyield H 109 and suggest that it be planted in final tests with H 109 and in reasonable field areas to test its reaction to regular plantation conditions.

A report from Pioneer Mill Company indicates that it suffers from wind damage, the tops being broken off. We therefore recommend that this cane be not planted in eye spot areas or in wind-swept fields.

25 C 4 and 25 C 7 also consistently outyielded the surrounding checks of H 109 in tonnage, especially the latter. This cane has received many favorable reports in the Caledonia regions. It has the ability to close in, and ratoon fast. Both canes are resistant to eye spot.

Another cane we should like to see tried out in final tests on irrigated plantations is 20 S 15. This is a Striped Mexican seedling. It is very resistant to eye spot. At Waipio it has consistently given good juices.

In 1927, it was first in quality out of sixteen, with a quality ratio of 7.96. The average of three H 109 plots in the same field was 9.36, and the average for all varieties was 9.27. This was plant cane eighteen months old when harvested in January. You will note that in the harvest this year in another field, it was again first with a quality ratio of 7.0, against a field average of 7.93, and 7.7 for adjoining H 109. In both of these harvests it has equalled H 109 in sugar production with the advantage of producing it from less cane. (See Fig. 2.)

Notes taken on the ratooning in this field one month after harvesting show that 25 C 7, 20 S 15 and 20 S 19 are all coming up faster than H 109, with 25 C 4, 25 C 19 and 25 C 34 about on a par with H 109.

The detailed plot yields for this year's harvest are given:

| Variety | Plot | Area | T. C. P. A. | T. S. P. A. | Brix | Pol. | Pur. | Q. R. |
|---------|------|------|-------------|-------------|------|-------|------|-------|
| 25 C 4 | 6.1 | .042 | 78.1 | | | | | |
| | 6.3 | .042 | 74.2 | | | | | |
| | 6.5 | .036 | 80.2 | | | | | |
| | | .120 | 77.4 | 9.33 | 19.7 | 16.61 | 84.3 | 8.3 |
| H 109 | 6.2 | .042 | 74.1 | | | | | |
| | 6.4 | .042 | 83.0 | | | | | |
| | 6.6 | .042 | 80.9 | | | | | |
| | | .126 | 79.3 | 8.18 | 17.4 | 14.38 | 82.8 | 9.7 |
| 25 C 7 | 7.2 | .043 | 81.5 | | | | | |
| | 7.4 | .043 | 80.4 | | | | | |
| | 7.6 | .043 | 86.9 | | | | | |
| | | .129 | 82.9 | 9.01 | 18.2 | 15.22 | 83.5 | 9.2 |
| H 109 | 7.1 | .043 | 70.3 | | | | | |
| | 7.3 | .043 | 69.6 | | | | | |
| | 7.5 | .036 | 72.0 | | | | | |
| | | .122 | 70.5 | 8.02 | 18.3 | 15.61 | 85.2 | 8.8 |
| 25 C 19 | 8.1 | .041 | 81.8 | | | | | |
| | 8.3 | .041 | 74.0 | | | | | |
| | 8.5 | .039 | 73.3 | | | | | |
| | | .121 | 76.4 | 10.0 | 19.7 | 15.84 | 80.2 | 7.64 |

| Variety | Plot | Area | T. C. P. A. | T. S. P. A. | Brix | Pol. | Pur. | Q. R. |
|---------|------|------|-------------|-------------|------|-------|------|-------|
| H 109 | 8.2 | .041 | 67.9 | | | | | |
| | 8.4 | .041 | 73.5 | | | | | |
| | 8.6 | .041 | 68.0 | | | | | |
| | .123 | | 69.7 | 7.89 | 17.9 | 15.23 | 84.9 | 8.84 |
| 25 C 32 | 9.2 | .044 | 55.7 | | | | | |
| | 9.4 | .044 | 61.5 | | | | | |
| | 9.6 | .044 | 59.2 | | | | | |
| | .132 | | 58.8 | 8.03 | 20.0 | 17.86 | 89.5 | 7.33 |
| H 109 | 9.1 | .044 | 70.5 | | | | | |
| | 9.3 | .044 | 70.6 | | | | | |
| | 9.5 | .039 | 65.7 | | | | | |
| | .127 | | 69.9 | 8.85 | 19.2 | 16.79 | 87.5 | 7.90 |
| 25 C 34 | 10.1 | .041 | 58.2 | | | | | |
| | 10.3 | .041 | 63.8 | | | | | |
| | 10.5 | .039 | 55.5 | | | | | |
| | .121 | | 59.2 | 6.35 | 18.1 | 14.67 | 81.7 | 9.33 |
| H 109 | 10.2 | .041 | 69.7 | | | | | |
| | 10.4 | .041 | 72.3 | | | | | |
| | 10.6 | .041 | 70.5 | | | | | |
| | .123 | | 70.8 | 8.80 | 19.1 | 16.53 | 86.8 | 8.05 |
| 20 S 15 | 11.2 | .042 | 67.8 | | | | | |
| | 11.4 | .042 | 67.7 | | | | | |
| | 11.6 | .037 | 67.8 | | | | | |
| | .121 | | 67.8 | 9.66 | 20.6 | 18.59 | 90.3 | 7.02 |
| H 109 | 11.1 | .042 | 70.7 | | | | | |
| | 11.3 | .042 | 73.6 | | | | | |
| | 11.5 | .042 | 60.5 | | | | | |
| | .126 | | 68.3 | 9.36 | 19.7 | 17.91 | 89.9 | 7.30 |
| 20 S 17 | 12.1 | .039 | 57.7 | | | | | |
| | 12.3 | .039 | 62.7 | | | | | |
| | 12.5 | .035 | 60.6 | | | | | |
| | .113 | | 60.3 | 7.42 | 17.3 | 15.93 | 91.7 | 8.13 |
| H 109 | 12.2 | .039 | 71.1 | | | | | |
| | 12.4 | .039 | 68.5 | | | | | |
| | 12.6 | .039 | 66.9 | | | | | |
| | .117 | | 68.9 | 8.90 | 19.1 | 16.98 | 89.0 | 7.74 |
| 20 S 18 | 13.2 | .041 | 70.0 | | | | | |
| | 13.4 | .041 | 77.1 | | | | | |
| | 13.6 | .037 | 74.1 | | | | | |
| | .119 | | 73.8 | 8.22 | 18.1 | 15.13 | 83.4 | 8.98 |
| H 109 | 13.1 | .041 | 81.5 | | | | | |
| | 13.3 | .041 | 84.1 | | | | | |
| | 13.5 | .041 | 65.6 | | | | | |
| | .123 | | 77.1 | 10.12 | 19.6 | 17.29 | 88.3 | 7.62 |

| Variety | Plot | Area | T. C. P. A. | T. S. P. A. | Brix | Pol. | Pur. | Q. R. |
|---------|------|------|-------------|-------------|------|-------|------|-------|
| 20 S 19 | 14.1 | .045 | 50.6 | | | | | |
| | 14.3 | .045 | 53.0 | | | | | |
| | 14.5 | .040 | 46.6 | | | | | |
| | | .130 | 50.2 | 6.41 | 19.7 | 16.98 | 86.3 | 7.83 |
| H 109 | 14.2 | .045 | 61.7 | | | | | |
| | 14.4 | .045 | 67.6 | | | | | |
| | 14.6 | .045 | 50.8 | | | | | |
| | | .135 | 58.7 | 7.29 | 19.7 | 16.75 | 84.8 | 8.05 |

Uba Hybrids at Honokaa Sugar Company

Honokaa Sugar Company has kindly supplied the following yield figures on a number of the Uba hybrids.

The test was conducted in Field 101, at an elevation of 400 feet, under overhead irrigation. Each plot contained 1/20th acre. Alternate plots were checks of D 1135:

| Variety | 1927 Crop—19 Months | | | Old Plant Cane | | 1928 Crop—18 Months | | | First Ratoons | | Plant and | |
|----------------|---------------------|---------------|-------|----------------|------|---------------------|---------------|-------|---------------|------|---------------|-----------|
| | Q. R. | Tons per Acre | Sugar | Gain | Loss | Q. R. | Tons per Acre | Sugar | Gain | Loss | First Ratoons | Plant and |
| | | | | T. S. P. A. | | | | | T. S. P. A. | | Gain | Loss |
| D 1135 | 14.1 | 86.4 | 6.13 | | | 13.5 | 52.1 | 3.85 | | | | |
| U. D. 1 | 9.2 | 100.4 | 10.91 | 3.63 | | 10.6 | 111.7 | 10.57 | 6.22 | | 9.85 | |
| D 1135 | 11.5 | 97.1 | 8.44 | | | 12.9 | 61.7 | 4.78 | | | | |
| U. H. 2 | 34.2 | 83.3 | 2.46 | | 6.29 | 18.4 | 60.6 | 3.29 | | 2.43 | | 8.72 |
| D 1135 | 11.9 | 107.9 | 9.06 | | | 11.4 | 75.9 | 6.66 | | | | |
| U. H. 4 | 12.4 | 126.6 | 10.21 | 2.43 | | 14.7 | 83.9 | 5.71 | 0.33 | | 2.76 | |
| D 1135 | 13.1 | 85.3 | 6.51 | | | 12.8 | 52.5 | 4.10 | | | | |
| U. H. 6 | 19.2 | 98.6 | 5.13 | | 2.13 | 15.8 | 96.4 | 6.10 | 1.34 | | | 0.69 |
| D 1135 | 11.0 | 88.1 | 8.01 | | | 10.4 | 56.4 | 5.42 | | | | |
| U. D. 7 | 13.2 | 117.3 | 8.89 | 2.17 | | 12.6 | 91.5 | 7.26 | 2.61 | | 4.78 | |
| D 1135 | 13.5 | 73.4 | 5.44 | | | 11.2 | 43.5 | 3.88 | | | | |
| U. D. 9 | 13.0 | 107.5 | 8.27 | 2.96 | | 12.4 | 115.2 | 9.29 | 4.94 | | 7.90 | |
| D 1135 | 16.4 | 85.0 | 5.18 | | | 11.3 | 54.6 | 4.83 | | | | |
| U. D. 13 | 14.6 | 91.3 | 6.23 | | 0.31 | 12.7 | 68.9 | 5.43 | 0.37 | | 0.06 | |
| D 1135 | 11.7 | 92.5 | 7.90 | | | 12.1 | 64.0 | 5.29 | | | | |
| D 1135 | 14.5 | 81.5 | 5.62 | | | 14.8 | 56.1 | 3.79 | | | | |
| U. D. 14 | 36.2 | 105.9 | 2.92 | | 2.42 | 17.8 | 107.9 | 6.06 | 2.35 | | | 0.07 |
| D 1135 | 16.0 | 81.1 | 5.07 | | | 13.5 | 49.1 | 3.64 | | | | |
| U. D. 21 | 26.9 | 111.6 | 4.15 | | 2.10 | 12.7 | 111.7 | 8.79 | 3.94 | | 1.84 | |
| D 1135 | 12.9 | 95.8 | 7.43 | | | 13.0 | 78.8 | 6.06 | | | | |
| U. D. 25 | 11.5 | 98.5 | 8.56 | 1.97 | | 19.0 | 85.3 | 4.49 | | 0.96 | 1.01 | |
| D 1135 | 13.1 | 75.3 | 5.75 | | | 9.7 | 46.9 | 4.84 | | | | |
| U. D. 26 | 14.8 | 85.3 | 5.87 | 0.29 | | 11.5 | 68.2 | 5.93 | 1.00 | | 1.29 | |
| D 1135 | 13.7 | 74.2 | 5.41 | | | 12.2 | 56.3 | 5.03 | | | | |
| U. D. 30 | 13.1 | 104.0 | 7.93 | 2.76 | | 14.5 | 85.5 | 5.90 | 1.44 | | 4.17 | |
| D 1135 | 13.5 | 66.8 | 4.93 | | | 13.2 | 52.3 | 3.96 | | | | |
| U. D. 35 | 16.3 | 129.1 | 7.91 | 2.53 | | 13.7 | 131.9 | 9.62 | 5.64 | | 8.17 | |
| D 1135 | 16.4 | 94.4 | 5.74 | | | 12.2 | 49.0 | 4.01 | | | | |
| U. D. 39 | 12.5 | 73.9 | 5.81 | | 0.60 | 10.8 | 79.9 | 7.40 | 2.40 | | 1.80 | |
| D 1135 | 11.7 | 83.4 | 7.09 | | | 11.6 | 69.4 | 5.98 | | | | |

| Variety | 1927 Crop—19 Months Old Plant Cane | | | 1928 Crop—18 Months Old First Ratoons | | | Plant and First Ratoons Gain Loss T. S. P. A. |
|-----------------|------------------------------------|-----------------------------|---------------------|---------------------------------------|-----------------------------|---------------------|--|
| | Q. R. | Tons per Acre Cane Sugar | Gain T. S. P. A. | Q. R. | Tons per Acre Cane Sugar | Gain T. S. P. A. | |
| D 1135 | 10.2 | 102.0 | 10.00 | 12.7 | 57.9 | -4.56 | |
| U. D. 56..... | 12.5 | 105.9 | 8.47 | 13.4 | 90.2 | 6.73 | 2.99 |
| D 1135 | 14.8 | 85.7 | 5.80 | 13.3 | 53.9 | 4.06 | |
| U. D. 58..... | 11.4 | 118.3 | 10.37 | 13.9 | 123.9 | 8.91 | 7.82 |
| D 1135 | 15.0 | 106.4 | 7.09 | 11.4 | 68.2 | 5.99 | |
| U. D. 65..... | 12.4 | 99.2 | 8.00 | 11.4 | 79.4 | 6.97 | 1.55 |
| D 1135 | 11.8 | 91.6 | 7.74 | 10.8 | 65.2 | 6.04 | |
| U. D. 67..... | 17.6 | 111.6 | 6.26 | 12.4 | 75.1 | 6.05 | 2.61 |
| D 1135 | 11.4 | 91.9 | 8.01 | 10.7 | 86.3 | 8.06 | |
| U. D. 70..... | 14.7 | 103.9 | 7.05 | 11.1 | 105.7 | 9.52 | 2.05 |
| D 1135 | 11.9 | 88.2 | 7.42 | 10.9 | 60.7 | 5.57 | |
| U. D. 79..... | 14.5 | 102.2 | 7.02 | 10.9 | 107.5 | 9.86 | 4.32 |
| D 1135 | 11.7 | 79.9 | 6.83 | 11.7 | 62.3 | 5.32 | |
| U. D. 100..... | 13.3 | 104.0 | 7.79 | 13.1 | 118.5 | 9.05 | 5.51 |
| D 1135 | 11.6 | 74.8 | 6.44 | 11.0 | 44.8 | 4.08 | |
| D 1135 | 11.5 | 78.9 | 6.83 | 12.7 | 66.9 | 5.27 | |
| U. D. 104..... | 10.4 | 107.5 | 10.33 | 12.2 | 85.4 | 7.00 | 5.36 |
| D 1135 | 10.6 | 72.9 | 6.88 | 11.4 | 56.2 | 4.93 | |
| U. D. 106..... | 13.3 | 76.8 | 5.77 | 13.8 | 79.1 | 5.74 | 0.36 |
| D 1135 | 14.2 | 73.6 | 5.88 | 12.2 | 52.1 | 4.27 | |
| U. D. 110..... | 12.5 | 84.4 | 6.75 | 10.9 | 92.4 | 8.48 | 4.85 |
| D 1135 | 12.8 | 85.3 | 6.71 | 11.3 | 52.2 | 4.62 | |
| P-2 | 16.3 | 133.7 | 8.19 | 13.2 | 94.8 | 7.18 | 2.26 |
| D 1135 | 13.8 | 98.6 | 7.21 | 10.7 | 82.2 | 7.68 | |
| U. B. 1..... | 17.7 | 92.6 | 5.24 | 20.8 | 67.7 | 3.38 | -3.50 |
| D 1135 | 10.3 | 91.6 | 8.86 | 10.4 | 63.3 | 6.09 | |
| H. U. H. 3..... | 10.3 | 71.3 | 6.92 | 10.1 | 86.3 | 8.54 | 2.25 |
| D 1135 | 10.2 | 66.2 | 6.48 | 12.7 | 63.2 | 4.98 | |
| Uba | 12.0 | 41.3 | 3.43 | 10.0 | 84.8 | 4.39 | 2.44 |
| D 1135 | 9.3 | 40.0 | 4.29 | 9.2 | 29.5 | 3.20 | |

| Variety | 1927 Crop—19 Months | | | Old Plant Cane | | | 1928 Crop—18 Months | | | Old First Ratoons | | | Plant and | |
|---------------|---------------------|-----------------------|-------|---------------------|------|--|---------------------|-----------------------|-------|---------------------|------|--|-----------------------|---------------------|
| | Q. R. | Tons per Acre Cane | Sugar | Gain T. S. P. A. | Loss | | Q. R. | Tons per Acre Cane | Sugar | Gain T. S. P. A. | Loss | | First Ratoons Gain | Loss T. S. P. A. |
| D 1135 | 13.7 | 71.0 | 5.19 | | | | 14.8 | 59.8 | 4.04 | | | | | |
| U. D. 28..... | 25.3 | 99.3 | 3.92 | | 2.46 | | 16.8 | 110.9 | 6.60 | 2.03 | | | | 0.43 |
| D 1135 | 10.3 | 78.1 | 7.58 | | | | 12.2 | 62.3 | 5.10 | | | | | |
| U. D. 37..... | 12.7 | 112.7 | 8.87 | 2.16 | | | 12.6 | 111.5 | 8.85 | 3.63 | | | 5.79 | |
| D 1135 | 12.3 | 71.9 | 5.84 | | | | 12.1 | 64.5 | 5.32 | | | | | |
| U. D. 41..... | 33.7 | 75.1 | 2.23 | | 5.32 | | 23.1 | 68.3 | 2.95 | | 2.86 | | | 8.18 |
| D 1135 | 10.5 | 97.3 | 9.26 | | | | 10.3 | 65.0 | 6.31 | | | | | |
| U. D. 47..... | 23.1 | 92.6 | 4.01 | | 4.89 | | 12.9 | 84.7 | 6.56 | 1.18 | | | | 3.71 |
| D 1135 | 10.2 | 86.9 | 8.54 | | | | 12.0 | 53.6 | 4.46 | | | | | |
| U. D. 50..... | 9.3 | 66.2 | 7.10 | | 0.19 | | 9.6 | 53.7 | 5.59 | | 0.09 | | | 0.10 |
| D 1135 | 10.6 | 64.0 | 6.04 | | | | 9.3 | 64.3 | 6.90 | | | | | |
| U. D. 60..... | 14.4 | 82.0 | 5.68 | 0.13 | | | 10.4 | 88.1 | 8.47 | 3.17 | | | 3.30 | * |
| D 1135 | 8.7 | 43.9 | 5.06 | | | | 9.9 | 36.6 | 3.70 | | | | | |
| Uba | 12.9 | 43.9 | 3.40 | | 1.15 | | 8.6 | 68.6 | 7.98 | 3.62 | | | 2.47 | |
| D 1135 | 9.9 | 40.0 | 4.04 | | | | 10.0 | 50.3 | 5.03 | | | | | |
| D 1135 | 14.7 | 86.1 | 5.86 | | | | 14.2 | 45.2 | 3.18 | | | | | |
| U. D. 11..... | 16.7 | 85.5 | 5.00 | | 1.25 | | 22.7 | 53.3 | 2.35 | | 1.47 | | | 2.72 |
| D 1135 | 10.0 | 66.4 | 6.64 | | | | 10.9 | 48.6 | 4.46 | | | | | |
| U. D. 71..... | 18.7 | 66.4 | 3.55 | | 3.82 | | 16.5 | 43.2 | 2.62 | | 1.96 | | | 5.78 |
| D 1135 | 9.7 | 78.6 | 8.10 | | | | 9.8 | 46.1 | 4.70 | | | | | |
| U. D. 75..... | 10.2 | 94.9 | 9.30 | 1.45 | | | 13.8 | 76.7 | 5.56 | 1.14 | | | 2.59 | |
| D 1135 | 9.97 | 75.8 | 7.60 | | | | 10.0 | 41.5 | 4.15 | | | | | |
| Uba | 11.1 | 90.1 | 8.14 | 1.30 | | | 11.3 | 115.1 | 10.18 | 5.53 | | | 6.83 | |
| D 1135 | 11.7 | 71.3 | 6.09 | | | | 11.4 | 58.9 | 5.16 | | | | | |
| U. D. 78..... | 13.6 | 86.9 | 6.37 | 0.37 | | | 12.4 | 65.7 | 5.30 | | 0.57 | | | 0.20 |
| D 1135 | 12.2 | 86.9 | 7.11 | | | | 12.1 | 79.7 | 6.59 | | | | | |
| U. D. 85..... | 17.9 | 88.5 | 6.14 | | 1.03 | | 18.3 | 88.4 | 4.83 | | 1.22 | | | 2.25 |
| D 1135 | 12.5 | 90.1 | 7.18 | | | | 10.6 | 55.1 | 5.20 | | | | | |
| U. D. 88..... | 11.8 | 110.0 | 7.84 | 2.13 | | | 12.4 | 66.4 | 5.35 | 0.24 | | | 2.37 | |
| D 1135 | 14.4 | 61.2 | 4.25 | | | | 10.0 | 50.3 | 5.03 | | | | | |

| Variety | 1927 Crop—19 Months | | | | Old Plant Cane | | 1928 Crop—18 Months | | | | First Ratoons | | Plant and First Ratoons Gain Loss T. S. P. A. |
|----------------|---------------------|-----------------------|-------|------|----------------|------|---------------------|-----------------------|-------|------|---------------|------|--|
| | Q. R. | Tons per Acre Cane | Sugar | Loss | T. S. P. A. | Gain | Q. R. | Tons per Acre Cane | Sugar | Gain | T. S. P. A. | Loss | |
| D 1135 | 10.5 | 61.3 | 4.28 | | | | 13.8 | 50.2 | 3.64 | | | | |
| U. D. 92 | 13.0 | 70.2 | 5.40 | | 0.04 | | 11.3 | 98.1 | 8.68 | 5.01 | | | 4.97 |
| D 1135 | 10.4 | 68.6 | 6.60 | | | | 11.6 | 43.0 | 3.70 | | | | |
| U. D. 94 | 11.4 | 62.6 | 5.58 | | 2.27 | | 13.2 | 57.1 | 4.32 | | | | |
| D 1135 | 8.8 | 80.2 | 9.11 | | | | 10.7 | 59.2 | 5.53 | | | | |
| U. H. 1 | 10.0 | 77.5 | 7.75 | | 1.60 | | 10.2 | 68.9 | 6.75 | 1.52 | | 2.57 | |
| D 1135 | 10.1 | 97.3 | 9.60 | | | | 11.2 | 59.4 | 4.94 | | | | 3.12 |
| U. B. 3 | 12.0 | 74.8 | 6.23 | | 1.97 | | 12.9 | 69.3 | 5.37 | 0.61 | | | 1.36 |
| D 1135 | 11.2 | 76.8 | 6.81 | | | | 12.9 | 59.2 | 4.59 | | | | |
| U. H. 3 | 27.5 | 147.3 | 5.36 | | 0.84 | | 16.2 | 104.6 | 6.45 | 2.26 | | | 1.41 |
| D 1135 | 13.5 | 75.8 | 5.59 | | | | 14.3 | 54.3 | 3.80 | | | | |
| U. D. 34 | 12.0 | 82.5 | 6.82 | 0.37 | | | 12.7 | 74.3 | 5.85 | 0.28 | | | 0.65 |
| D 1135 | 11.2 | 82.0 | 7.31 | | | | 11.5 | 84.4 | 7.34 | | | | |
| U. D. 6 | 14.1 | 80.0 | 5.68 | | 1.21 | | 12.9 | 80.1 | 6.21 | 0.13 | | 0.08 | |
| D 1135 | 13.4 | 86.9 | 6.48 | | | | 11.6 | 56.1 | 4.83 | | | | |
| D 1135 | 11.6 | 98.0 | 8.44 | | | | 12.1 | 82.2 | 6.88 | | | | |
| U. D. 75 | 11.0 | 133.8 | 12.17 | 5.36 | | | 13.0 | 108.7 | 8.36 | 2.90 | | | 8.26 |
| D 1135 | 13.7 | 71.0 | 5.19 | | | | 14.8 | 59.8 | 4.04 | | | | |

E. E. Naquin has the following to say concerning the Uba hybrids in the above test:

The merits of seedlings as commercial canes were pointed out in the writings of the previous crop, harvested in February, 1927. Their values commercially remain about the same, with a few exceptions.

H. U. H. 6, U. D. 14, 21, 26, 28, 35, 47, 60, 70 and 79, which are generally good yielders, but poor in the quality of their juices, show much better juices in the ratoon than in the previous plant crop. This accounts for their increase in sugar over the plant crop, the cane yield being about the same as in previous crops. Of the above seedlings H. U. H. 6, U. D. 14 and U. D. 28 showed the poorest juices.

Among the most promising seedlings the following give in the ratoon crop an actual increase in sugar per acre as compared with the plant crop: U. D. 9, 39, 70, 79, 92, 100, 110 and Uba. They all show a slight increase in tonnage, but a considerable improvement in the quality of the juices.

U. D. 1 and 37 have about an even break in sugar per acre as compared with the previous crop, while U. H. 4, U. D. 7, 75, 104 and P-2 show a decrease in yield of cane per acre with variable quality ratio. U. D. 58 shows an increase in cane yield, but an inferior quality ratio as compared with the plant crop.

In comparing the yields of the two crops with our standard cane, D 1135, we note a much larger gain in yield of sugar per acre in the first ratoons as compared with the plant crop. This is largely due to the great decrease in the yield of our standard cane D 1135. The average yield of sugar per acre of D 1135 was 6.89 for the 1927 crop and 5.06 tons for the 1928 crop. This decrease was directly due to the crowding out of the D 1135 by the rapid and rank growth of the Uba seedlings.

It is interesting to note that Uba shows a better quality of juices than any of its offspring.

In connection with the above test it may not be out of place to call attention to the performance of some of the Uba hybrids on other plantations.

U. D. 1 is too well known to require comment. We are all familiar with its fine vigor and ratooning power. Except for its susceptibility to eye spot and its tendency toward poor juices, it would be a super cane.

U. D. 4 is attracting interest at Kilauea. It has shown itself in several tests to be able to outyield its sisters and the older P. O. J.'s, under certain Kilauea conditions.

U. D. 50 is showing up well at Hutchinson plantation. It has the largest stick of any of this series, but has usually fallen down in ratooning. At Hutchinson, however, it seems to have found conditions to its liking and is ratooning quite satisfactorily.

U. D. 62 is another large-sticked cane. It promises to be useful in H 109 chlorosis areas. Ewa has planted a number of its coral chlorosis spots to U. D. 62, with indications of good success.

Under mauka conditions generally, both on Hawaii and Kauai, U. D. 9, 58, 75, 100 and 110 are the leaders. The latter cane grows better at high altitudes than any other cane we have seen thus far.

The fact that the canes named have come from a handful of only 110 seedlings points to Uba blood as one of the most promising for hard conditions. Every effort is being made to produce Uba hybrids and quarterbreeds in large numbers.

About 800 Uba hybrids were produced last year, mostly from Uba \times H 456. They are a very promising lot, with larger sticks than the Uba \times D 1135 seedlings, with no symptoms of node gall thus far and, on the whole, with good juices.

Uba germinations for this season are still under way, but indications are that between 600 and 1,000 will be obtained from various males.

Natal Uba seems especially promising as breeding material. It tassels earlier than Hawaiian Uba, at a time when pollen from other canes is still obtainable. It also seems to produce seedlings somewhat more freely, and the seedlings tend to be less grassy than those from Hawaiian Uba.

A. J. M.

Variety Tests at Olaa Sugar Company

By RAYMOND K. CONANT

INTRODUCTION

Some of the more outstanding cane varieties at Olaa, which showed promise of being competitors of D 1135, were selected in 1927 from a number of seedlings on the plantation and planted in fair variety tests with D 1135. One test was planted in an upper field and another in a middle belt field, where D 1135 is the standard cane.

The varieties selected for these tests were not considered suitable to lower land conditions where Yellow Caledonia is the standard. In view of this and the fact that no other seedlings planted on these lower areas showed promise, the tests were confined to the above mentioned areas.

The canes selected for these tests were K 107, U. D. 1, P. O. J. 979, K 202 and P. O. J. 36.

PLAN OF THE EXPERIMENTS

Olaa Variety Experiment 27-6 was located in Field J-1, Section D-1, elevation about 500 feet. The layout consisted of sixty-four plots, twenty-three of which were 1/40 acre in size, and forty-one of which were 1/20 acre in size. Each plot consisted of six straight lines, each line being 4.5 feet in width. The length of the lines was 40.3 feet for the 1/40 acre plots and 80.6 feet for the 1/20 acre plots. Every plot of each variety had an adjoining check plot of D 1135, so that we may consider the experiment in five separate parts.

Seed of the same age and condition was used for all canes.

Mudpress was applied to all plots at the rate of 12 tons per acre with the seed. Commercial fertilizer was applied uniformly to all plots in four applications so as to give 200 pounds nitrogen per acre, 20 pounds P_2O_5 per acre, and 200 pounds K_2O per acre. Cultivation was uniform to all plots.

Experiment 27-7 was located in Field 4-5, Section E, elevation about 1,700 feet. The layout of the experiment consisted of seventy plots. All plots were 1/20 acre in size, consisting of six straight lines. Each line was 4 feet in width and 90.75 feet in length. Again every plot of each variety had an adjoining check plot of D 1135, making five parts to the experiment.

The seed, fertilization and cultivation was uniform to all plots. In this experiment 500 pounds of bone meal was applied with the seed. Subsequent fertilization was the same as in Experiment 27-6.

HARVESTING PROCEDURE

In both experiments all six lines of each plot were cut and bundled. Every bundle in each plot was weighed. The trash deduction was obtained by taking trash weights on two bundles in each plot, the fifth bundle from either end of the two center lines being scaled for this purpose.

One bundle from each plot was taken for juice analyses. The bundle consisted of ten stalks taken at random through the plot. Each bundle was ground separately and 300 c.c. of juice from similar plots were mixed to make a composite sample and the analyses were made on the composite sample.

HARVESTING RESULTS

Olaa Sugar Company, Experiment 27-6, 1929 Crop. Field J-1, Section D-1, Elevation 500 feet. Variety Experiment.

Object: To compare K 107, U. D. 1, P. O. J. 979, K 202 and P. O. J. 36 with D 1135.

Layout: 64 plots, 1-41 inclusive, 1/20 acre each, consisting of 6 straight lines. Each line 80.6 feet by 4.5 feet. Plots 42-64 inclusive 1/40 acre each, consisting of 6 straight lines. Each line being 40.3 feet by 4.5 feet.

Plant Cane: Planted March, 1927.

Area: 2.625 acres.

Age at harvest: 23 months.

Harvested: February, 1929.

Results:

| Plots | No. of Plots | Part | Mudpress With Seed | Fertilization in | | | Juice Analyses | | | | Yields | | | |
|--------------|-----------------|------|-----------------------|------------------|-------------------------------|---------------|----------------|-------|------|---|------------------------------|-------|-------------------|-------|
| | | | | N | P ₂ O ₅ | Lbs. per Acre | Brix | Poln. | Pur. | Per Cent P ₂ O ₅ | Per Cent K ₂ O | Q. R. | T. C./A. T. S./A. | |
| K 107 | 7 | I | 12 T. p. a. | 200 | 20 | 200 | 18.2 | 16.50 | 90.7 | .024 | .048 | 7.91 | 62.60 | 7.92 |
| D 1135 | 7 | I | " | 200 | 20 | 200 | 18.1 | 16.80 | 92.8 | .024 | .057 | 7.68 | 63.19 | 8.22 |
| U. D. I | 7 | II | " | 200 | 20 | 200 | 16.6 | 15.49 | 93.3 | .017 | .044 | 8.29 | 92.13 | 11.11 |
| D 1135 | 7 | II | " | 200 | 20 | 200 | 16.9 | 15.39 | 91.1 | .018 | .035 | 8.40 | 46.01 | 5.47 |
| P. O. J. 979 | 4 | III | " | 200 | 20 | 200 | 17.2 | 16.06 | 93.4 | .016 | .044 | 7.97 | 46.38 | 5.81 |
| D 1135 | 4 | III | " | 200 | 20 | 200 | 17.4 | 15.91 | 91.4 | .020 | .061 | 8.16 | 56.92 | 6.97 |
| K 202 | 6 | IV | " | 200 | 20 | 200 | 16.9 | 15.39 | 93.7 | .025 | .048 | 8.46 | 53.02 | 6.27 |
| D 1135 | 7 | IV | " | 200 | 20 | 200 | 18.1 | 16.98 | 91.0 | .018 | .055 | 7.55 | 54.31 | 7.19 |
| P. O. J. 36 | 7 | V | " | 200 | 20 | 200 | 17.2 | 16.00 | 93.0 | .028 | .053 | 8.05 | 101.65 | 12.62 |
| D 1135 | 8 | V | " | 200 | 20 | 200 | 16.0 | 14.42 | 90.2 | .026 | .072 | 9.08 | 55.02 | 6.06 |

(See Fig. 1.)

LAYOUT OF OLAA VARIETY EXPERIMENT 27-6
WITH TONS CANE PER ACRE OF EACH PLOT

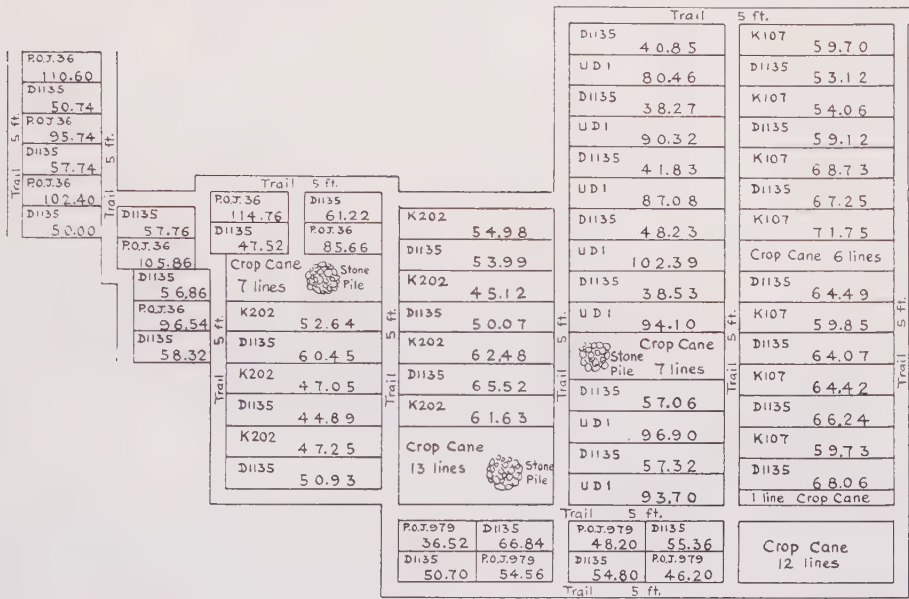


Fig. 1

The following table shows the T. C. P. A. and T. S. P. A. gain or loss figures of each cane in direct comparison with their respective checks of D 1135:

| Variety | T. C. P. A. | T. S. P. A. | T. C. P. A. | | T. S. P. A. | | Per Cent | | Per Cent | |
|--------------|-------------|-------------|--------------|-----|--------------|-----|--------------|------|--------------|------|
| | | | Gain or Loss | | Gain or Loss | | Gain or Loss | | Gain or Loss | |
| K 107 | 62.60 | 7.92 | — | .59 | — | .30 | — | .94% | — | 3.8% |
| D 1135 | 63.19 | 8.22 | | | | | | | | |
| U. D. 1 | 92.13 | 11.11 | +46.12 | | +5.64 | | +100 | % | +103 | % |
| D 1135 | 46.01 | 5.47 | | | | | | | | |
| P. O. J. 979 | 46.38 | 5.81 | —10.54 | | —1.16 | | — 22 | % | — 19.9 | % |
| D 1135 | 56.92 | 6.97 | | | | | | | | |
| K 202 | 53.02 | 6.27 | — 1.29 | | — .92 | | — 2.4 | % | — 14 | % |
| D 1135 | 54.31 | 7.19 | | | | | | | | |
| P. O. J. 36 | 101.65 | 12.62 | +46.63 | | +6.56 | | + 84 | % | +108 | % |
| D 1135 | 55.02 | 6.06 | | | | | | | | |

(See Fig. 2.)

TONS CANE PER ACRE AND TONS SUGAR PER ACRE OF EACH
CANE IN DIRECT COMPARISON WITH THEIR RESPECTIVE CHECKS OF D-1135.
OLAA SUGAR CO. FIELD J I, SECTION D I. ELEVATION 500 FT. VARIETY EXP. 27-6.

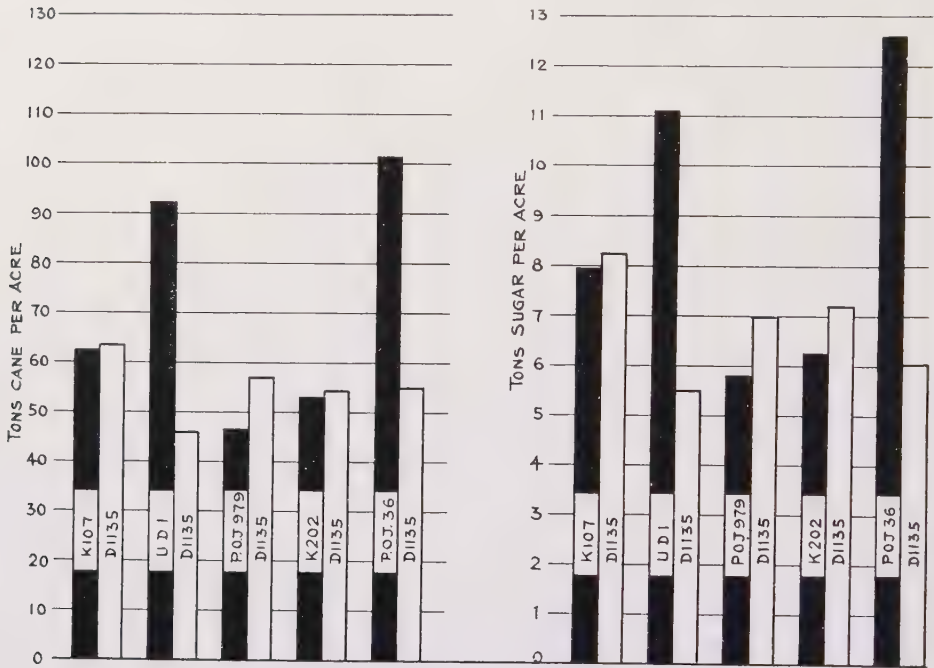


Fig. 2

Olaa Sugar Company, Experiment 27-7, 1929 Crop, Field 4-5, Section E, Elevation 1700 Feet. Variety Experiment.

Object: To compare P. O. J. 979, K 202, U. D. 1, K 107 and P. O. J. 36 with D 1135.

Layout: 70 plots, 1/20 acre each, consisting of 6 straight lines. Each line 4 feet by 90.75 feet.

Plant Cane: Planted April, 1927.

Area: 3.5 acres.

Age at Harvest: 22 months.

Harvested: February, 1929.

Results:

| Plots | No. of Plots | Part | Bonemeal With Seed | Fertilization in | | | | Juice Analyses | | | | Yields | | | | |
|--------------|-----------------|------|-----------------------|------------------|-------------------------------|------------------|---------------|----------------|-------|------|-------------------------------|----------|------------------|-------|----------|----------|
| | | | | N | P ₂ O ₅ | K ₂ O | Lbs. per Acre | Brix | Poln. | Pur. | P ₂ O ₅ | Per Cent | K ₂ O | Q. R. | T. C./A. | T. S./A. |
| P. O. J. 979 | 6 | I | 500 lbs. p. a. | 200 | 20 | 200 | 200 | 17.3 | 15.70 | 90.8 | .009 | .046 | .046 | 8.29 | 61.76 | 7.45 |
| D 1135 | 7 | I | " | 200 | 20 | 200 | 200 | 16.8 | 15.10 | 89.9 | .015 | .065 | .065 | 8.65 | 59.12 | 6.84 |
| K 202 | 7 | II | " | 200 | 20 | 200 | 200 | 16.2 | 14.62 | 90.2 | .021 | .051 | .051 | 8.95 | 48.75 | 5.45 |
| D 1135 | 7 | II | " | 200 | 20 | 200 | 200 | 17.9 | 16.61 | 92.8 | .015 | .039 | .039 | 7.76 | 55.26 | 7.12 |
| U. D. 1 | 7 | III | " | 200 | 20 | 200 | 200 | 16.6 | 15.47 | 93.2 | .015 | .048 | .048 | 8.30 | 72.22 | 8.70 |
| D 1135 | 7 | III | " | 200 | 20 | 200 | 200 | 17.1 | 15.73 | 92.0 | .015 | .051 | .051 | 8.24 | 51.04 | 6.20 |
| K 107 | 7 | IV | " | 200 | 20 | 200 | 200 | 18.4 | 16.75 | 91.0 | .018 | .046 | .046 | 7.76 | 67.30 | 8.67 |
| D 1135 | 7 | IV | " | 200 | 20 | 200 | 200 | 16.8 | 15.23 | 90.7 | .014 | .068 | .068 | 8.58 | 68.61 | 7.99 |
| P. O. J. 36 | 7 | V | " | 200 | 20 | 200 | 200 | 16.0 | 14.37 | 89.8 | .016 | .052 | .052 | 9.08 | 80.86 | 8.90 |
| D 1135 | 7 | V | " | 200 | 20 | 200 | 200 | 15.5 | 13.62 | 87.9 | .015 | .065 | .065 | 9.74 | 63.32 | 6.50 |

(See Fig. 3.)

LAYOUT OF OLAA VARIETY EXPERIMENT 27-7
WITH TONS CANE PER ACRE OF EACH PLOT

| Trail 5 ft. | | | Trail 5 ft. | | | Trail 5 ft. | | Trail 5 ft. | |
|-------------|-------|-------|-------------|--------|-------|-------------|-------|---------------------|-------|
| D1135 | 69.76 | K107 | 80.80 | D1135 | 63.80 | P.O.J.979 | 71.00 | D1135 | 65.99 |
| P.O.J.36 | 84.07 | D1135 | 69.38 | U.D.1 | 78.21 | D1135 | 56.80 | P.O.J.979 | 67.86 |
| D1135 | 50.96 | K107 | 62.51 | D1135 | 52.82 | K202 | 55.90 | D1135 | 58.40 |
| P.O.J.36 | 84.21 | D1135 | 67.72 | U.D.1. | 72.65 | D1135 | 61.37 | P.O.J.979 | 61.72 |
| D1135 | 72.58 | K107 | 68.49 | D1135 | 50.98 | K202 | 48.52 | D1135 | 58.70 |
| P.O.J.36 | 82.97 | D1135 | 66.77 | U.D.1. | 75.35 | D1135 | 48.52 | P.O.J.979 | 56.72 |
| D1135 | 61.88 | K107 | 60.35 | D1135 | 50.77 | K202 | 46.75 | D1135 | 57.60 |
| P.O.J.36 | 68.70 | D1135 | 72.28 | U.D.1. | 77.24 | D1135 | 48.68 | P.O.J.979 | 55.16 |
| D1135 | 66.56 | K107 | 54.64 | D1135 | 49.69 | K202 | 47.88 | D1135 | 58.65 |
| P.O.J.36 | 80.57 | D1135 | 77.16 | U.D.1. | 73.89 | D1135 | 54.35 | P.O.J.979 | 58.12 |
| D1135 | 60.95 | K107 | 81.91 | D1135 | 51.73 | K202 | 47.80 | D1135 | 57.73 |
| P.O.J.36 | 82.17 | D1135 | 63.29 | U.D.1. | 61.14 | D1135 | 57.31 | This Plot Discarded | |
| D1135 | 60.55 | K107 | 62.41 | D1135 | 37.52 | K202 | 49.60 | | |
| P.O.J.36 | 83.39 | D1135 | 63.71 | U.D.1. | 67.10 | D1135 | 56.00 | | |
| | | | | | | K202 | 44.83 | | |
| | | | | | | D1135 | 60.63 | | |

Fig. 3

T. C. P. A. and T. S. P. A. gain or loss figures of each cane in direct comparison with their respective checks of D 1135, for Experiment 27-7, follow:

| Variety | T. C. P. A. | T. S. P. A. | T. C. P. A. | | T. S. P. A. | | Per Cent | |
|--------------|-------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | | | Gain or Loss | Gain or Loss | Gain or Loss | Gain or Loss | Gain or Loss | Gain or Loss |
| P. O. J. 979 | 61.76 | 7.45 | + 2.64 | + .61 | + 4.4% | + 9 % | | |
| D 1135 | 59.12 | 6.84 | | | | | | |
| K 202 | 48.75 | 5.45 | — 6.51 | —1.67 | —13.4% | —30 % | | |
| D 1135 | 55.26 | 7.12 | | | | | | |
| U. D. 1 | 72.22 | 8.70 | +21.18 | +2.50 | +41.5% | +40.4% | | |
| D 1135 | 51.04 | 6.20 | | | | | | |
| K 107 | 67.30 | 8.67 | — 1.31 | + .68 | — 1.9% | + 8.5% | | |
| D 1135 | 68.61 | 7.99 | | | | | | |
| P. O. J. 36 | 80.86 | 8.90 | +17.54 | +2.40 | +27.7% | +36.9% | | |
| D 1135 | 63.32 | 6.50 | | | | | | |

(See Fig. 4.)

TONS CANE PER ACRE AND TONS SUGAR PER ACRE OF EACH
CANE IN DIRECT COMPARISON WITH THEIR RESPECTIVE CHECKS OF D-1135.
OLAA SUGAR CO. FIELD 4-5, SECTION E. ELEVATION 1700 FT. VARIETY EXP. 27-7.

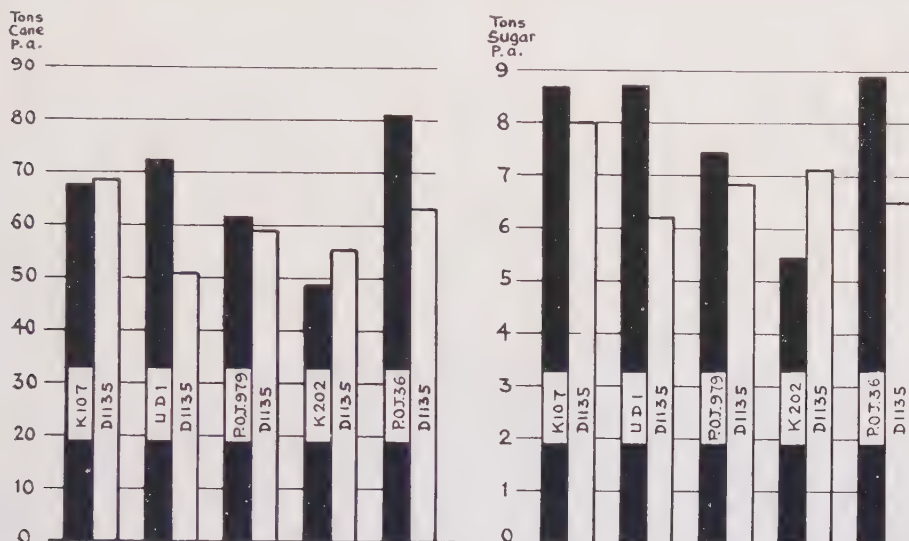


Fig. 4

DISCUSSION OF RESULTS

In these two tests P. O. J. 36 and U. D. 1 were the outstanding canes. In Experiment 27-6, U. D. 1 gave an increase of 100 per cent in cane over D 1135, and 103 per cent in sugar. P. O. J. 36 gave an increase of 84 per cent in cane and 108 per cent in sugar over D 1135.

In Experiment 27-7, U. D. 1 gave an increase of 41.5 per cent in cane and 40.4 per cent in sugar. Here P. O. J. 36 gave an increase in cane of 27.7 per cent and 36.9 per cent in sugar over D 1135.

From these figures we might conclude that P. O. J. 36 is the better cane to plant in the middle belt and U. D. 1 a superior cane to extend on the upper lands of Olaa.

P. O. J. 36 appears highly resistant or immune to many cane diseases to which U. D. 1 is susceptible. Eye spot, mosaic, and node galls have appeared on U. D. 1 at Olaa, but not on P. O. J. 36. Eye spot on U. D. 1 has been the most prevalent and severe of the above diseases. Node galls have occurred occasionally on this cane, and mosaic frequently, but not severely enough to cause a noticeable effect on its growth.

Both of these canes have the ability to close in rapidly and suppress weed growth, germinate very well from seed, and have shown themselves to be good ratooners at Olaa, with U. D. 1 having the advantage in this respect. With a cropping system that involves both short and long crops, P. O. J. 36 has the advantage in juice qualities and the ability to hold over on the long crop. Both canes tassel heavily under certain conditions, but they rarely tassel in the middle belt and mauka areas of Olaa.

The points in favor of U. D. 1 as an upper land cane at Olaa are numerous, but one serious fault which would seem to automatically bar it from the list as a commercial cane, is the fact that it is susceptible to cane diseases which are known to cause losses in yields. Hence it is perhaps plausible to contend that P. O. J. 36 is more suitable for middle belt and mauka areas at Olaa than U. D. 1.

The other varieties tried out against D 1135 in these tests gave returns greatly inferior to P. O. J. 36 and U. D. 1. The K 107 plots were very irregular in yields, due perhaps to poor germination and mosaic disease. It is interesting to note that 25 per cent infection with mosaic disease was found on K 107 in Experiment 27-6. The juices here were poorer than that of D 1135. In Experiment 27-7 mosaic disease was not present on K 107 and its juices in this experiment were superior to D 1135.

K 107 is slow in starting at Olaa, and does not suppress weeds satisfactorily. Honohono climbs all over it when it gets older, making the harvesting and subsequent weeding very expensive. It is only a fair ratooner under Olaa conditions.

K 202 was poorer than D 1135 in both experiments. It had poor juices and was infected with mosaic disease. Weed growth was plentiful in the plots. The ratoons appear to be fair with this cane at Olaa.

P. O. J. 979 did not hold over in Experiment 27-6, much dead cane being present when the plots were harvested. It is too upright in growth habits, not having sufficient leaf spread for suppressing weeds. In both experiments dead tops were present on this cane when the plots were harvested. This is a typical indication of iron accumulation in the nodal joints. The iron test with a 10 per cent solution of potassium thiocyanate and dilute hydrochloric acid gave a positive reaction on these stalks with dead tops.

SUMMARY

1. P. O. J. 36 gave a greater increase in sugar over D 1135 in the middle belt area, and U. D. 1 gave a greater increase in sugar over D 1135 in the upper land area.

2. Because of its susceptibility to dangerous cane diseases, U. D. 1 is perhaps automatically barred as a commercial cane even on the upper lands at Olaa Sugar Company.

3. P. O. J. 36 gave a substantial increase over D 1135 in both areas. Even though this increase over D 1135 in the upper land area was not as large as that shown by U. D. 1, yet because of its disease resistance P. O. J. 36 perhaps is the better cane for these Olaa areas.

4. The other varieties tried out against D 1135 in these experiments, viz., K 107, K 202, P. O. J. 979, gave inferior returns as compared to P. O. J. 36 and U. D. 1.

The writer is indebted to A. J. Watt, W. W. G. Moir, and the field and chemical staffs of Olaa Sugar Company for their kind advice and willing cooperation in these two endeavors.

Phosphoric Acid and Potash

WAIPIO EXPERIMENT V

By J. A. VERRET

This experiment was started with the 1917 crop and has been continued ever since. The average yields of eight crops from 1917 to 1927 were slightly in favor of the nitrogen plots. The differences were too small to be significant and were likely due to the natural difficulties of conducting field experiments. These results are summarized herewith:

| Crop Year | Tons Cane per Acre | | | | Q. R. | | | | Tons Sugar per Acre | | | |
|-----------|--------------------|-------|-------|-------|--------------|-------|-------|-------|---------------------|-------|-------|-------|
| | N | NP | NK | NPK | N | NP | NK | NPK | N | NP | NK | NPK |
| | Plots | Plots | Plots | Plots | Plots | Plots | Plots | Plots | Plots | Plots | Plots | Plots |
| 1917 | 54.4 | 50.2 | 52.8 | 51.5 | 8.77 | 9.09 | 9.01 | 8.91 | 6.20 | 5.52 | 5.86 | 5.89 |
| 1918 | 55.3 | 54.5 | 53.8 | 53.7 | 9.54 | 9.10 | 9.34 | 9.18 | 5.80 | 5.99 | 5.75 | 5.85 |
| 1919 | 50.8 | 51.1 | 50.4 | 50.4 | 8.36 | 8.28 | 8.66 | 8.52 | 6.08 | 6.17 | 5.82 | 5.91 |
| 1921 | 85.0 | 84.2 | 78.8 | 82.7 | 9.15 | 9.15 | 9.15 | 9.15 | 9.29 | 9.20 | 8.61 | 9.00 |
| 1923 | 125.8 | 127.2 | 119.9 | 124.4 | 8.26 | 8.46 | 8.23 | 8.36 | 15.24 | 15.04 | 14.57 | 15.25 |
| 1924 | 73.7 | 74.0 | 74.1 | 74.5 | Samples lost | | | | | | | |
| 1926 | 110.2 | 113.1 | 105.7 | 110.2 | 8.36 | 9.12 | 8.50 | 8.64 | 13.19 | 12.40 | 12.44 | 12.75 |
| 1927 | 77.1 | 76.5 | 76.2 | 76.2 | 8.60 | 8.55 | 8.71 | 8.46 | 8.97 | 8.95 | 8.74 | 9.00 |
| Avg. | 79.0 | 78.8 | 76.4 | 77.9 | 8.72 | 8.82 | 8.80 | 8.73 | 9.25 | 9.04 | 8.83 | 9.09 |

The 1929 crop for the first time showed good gains for the plots getting complete fertilizer over the nitrogen plots. This is shown graphically in Fig. 1. Nitrogen plots Nos. 1 and 60 are corner, level ditch plots and are likely to be unduly favored. If these plots are omitted the results are rather consistently in favor of the complete fertilizer.

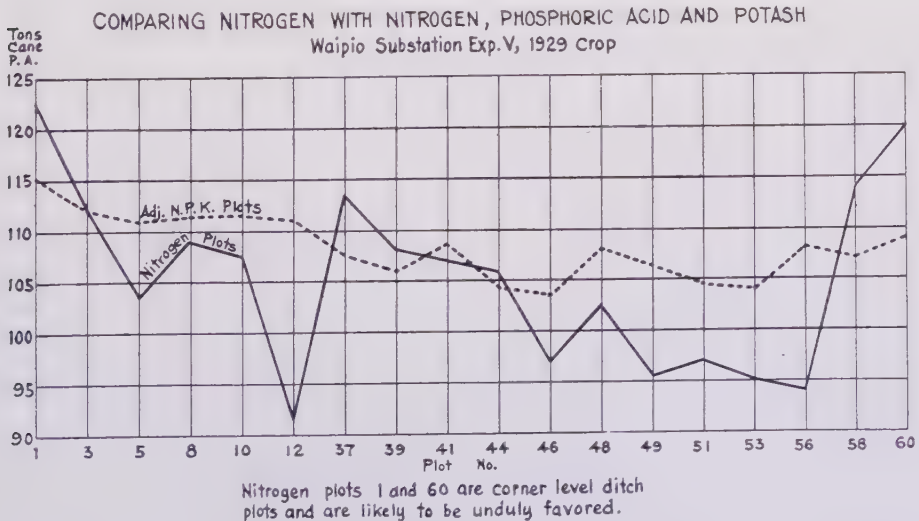


Fig. 1

WAIPIO SUBSTATION EXP. V, 1929 CROP

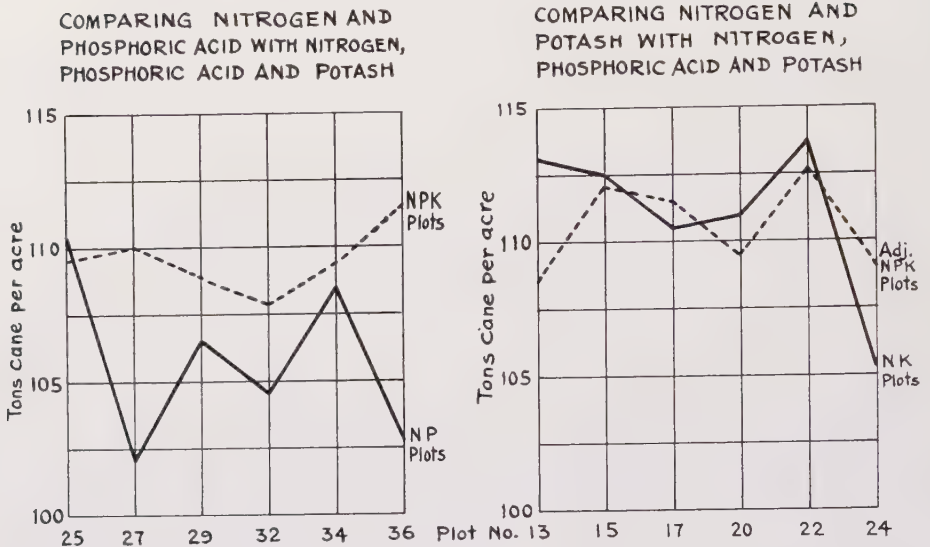


Fig. 2

In Fig. 2 we show by means of curves the comparative yields of plots getting nitrogen and phosphoric acid and nitrogen and potash with adjoining plots getting complete fertilizer.

These curves show significant gains of the complete fertilizer plots over adjoining plots getting only nitrogen and phosphoric acid. Such is not the case when we compare complete fertilizer plots with adjoining plots getting nitrogen and potash only. This indicates that the response is largely from potash.

This is exactly what one would expect from a study of the soil analysis as reported by Mr. Stewart, of the chemistry department:

| Treatment | Soil Reaction pH | 1 Per Cent Citric Acid Soluble | | | | Total by Fusion | |
|-----------|------------------------|--------------------------------|-----------------|------------------------------|---|------------------------------|---|
| | | Silica Per Cent | CaO Per Cent | K ₂ O Per Cent | P ₂ O ₅ Per Cent | K ₂ O Per Cent | P ₂ O ₅ Per Cent |
| N Plots | 6.9 | 0.16 | 0.17 | 0.023 | 0.0052 | 0.82 | 0.51 |
| NP Plots | 6.8 | 0.16 | 0.19 | 0.039 | 0.0100 | 0.50 | 0.48 |
| NK Plots | 6.8 | 0.16 | 0.15 | 0.045 | 0.0040 | 0.47 | 0.46 |
| NPK Plots | 7.0 | 0.17 | 0.21 | 0.028 | 0.0114 | 0.62 | 0.54 |

These analyses show a good supply of available P₂O₅ in all except the NK plots. These are just above the minimum supply and are likely soon to show more response to phosphate. The reverse is the case with the available potash where we find all plots to be low except the NK plots.

It is unfortunate that we did not have the analysis of these soils when the test was started. This is due to the fact that when this experiment was started the 1 per cent citric acid method had not yet been studied here and applied to our Island soils.

We feel that these results are extremely important in showing, as they do, how essential it is to carry on plant food tests in all areas where phosphoric acid and/or potash are omitted* or applied in small quantities, in our fertilizer practices.

Here we have a case where for ten years phosphoric acid and potash were not needed and then we have distinct indications that the potash supply is getting low and needs to be built up.

PLANT FOOD TEST
H 109-4th RATOONS 20 MONTHS OLD
Waipio Substation Exp.V, 1929 Crop
Tons cane per acre for each plot

| | | | | | | | | | | |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|----------------|---------------|
| 55 NPK 108.4 | 49 N 95.6 | 43 NPK 106.7 | 37 N 113.6 | 31 NPK 111.7 | 25 NP 110.4 | 19 NPK 104.7 | 13 NK 113.2 | 7 NPK 108.9 | 1 N 122.6 | Road Field |
| 56 N 94.0 | 50 NPK 103.8 | 44 N 105.9 | 38 NPK 104.4 | 32 NP 104.5 | 26 NPK 111.8 | 20 NK 111.0 | 14 NPK 111.7 | 8 N 109.0 | 2 NPK 121.7 | |
| 57 NPK 111.6 | 51 N 96.8 | 45 NPK 102.2 | 39 N 108.1 | 33 NPK 103.8 | 27 NP 102.2 | 21 NPK 109.5 | 15 NK 112.6 | 9 NPK 103.1 | 3 N 111.8 | |
| 58 N 113.9 | 52 NPK 100.0 | 46 N 97.0 | 40 NPK 114.1 | 34 NP 108.4 | 28 NPK 114.5 | 22 NK 113.8 | 16 NPK 123.9 | 10 N 107.6 | 4 NPK 110.9 | |
| 59 NPK 109.6 | 53 N 95.2 | 47 NPK 98.2 | 41 N 106.8 | 35 NPK 104.8 | 29 NP 106.4 | 23 NPK 102.9 | 17 NK 110.5 | 11 NPK 107.7 | 5 N 103.6 | |
| 60 N 120.0 | 54 NPK 108.5 | 48 N 102.6 | 42 NPK 116.8 | 36 NP 102.8 | 30 NPK 113.3 | 24 NK 105.3 | 18 NPK 111.0 | 12 N 91.7 | 6 NPK 113.9 | |
| Field Road | | | | | | | | | | |

Fig. 3

Unless these plant food tests are carried on from year to year we stand the chance of, some day, suffering serious losses.

The detailed layout and results from the 1929 crop are given as follows and shown in Fig. 3:

Object: Plant food test.

Location: Waipio Substation—Experiment V.

Crop: 1929 crop—4th ratoons—20 months old.

Layout: 60 plots approximately 1/30 acre, consisting of 8 lines with one guard on mauka and one on makai.

FERTILIZATION

| Plots | July, 1927 | | | Sept., 1927-Feb., 1928 | | | Totals | |
|-------|------------|-----------|-----------|------------------------|-------|-----|-------------------------------|------------------|
| | A. S. | Sul. Pot. | Ad. Phos. | A. S. | A. S. | N | P ₂ O ₅ | K ₂ O |
| N | 361 | ... | .... | 488 | 617 | 302 | 0 | 0 |
| NP | 361 | ... | 1190 | 488 | 617 | 302 | 250 | 0 |
| NK | 361 | 500 | .... | 488 | 617 | 302 | 0 | 250 |
| NPK | 361 | 500 | 1190 | 488 | 617 | 302 | 250 | 250 |

The guard rows were fertilized the same as N plots.

SUMMARY OF RESULTS

| Plots | Treatment | | | Yields per Acre | | |
|---------------------|-----------|-------------------------------|------------------|-----------------|-------|-------|
| | N | P ₂ O ₅ | K ₂ O | Cane | Q. R. | Sugar |
| N | 302 | 0 | 0 | 105.2 | 9.06 | 11.61 |
| Adjoining NPK | 302 | 250 | 250 | 108.8 | 8.85 | 12.29 |
| NP | 302 | 250 | 0 | 106.6 | 8.82 | 12.09 |
| Adjoining NPK | 302 | 250 | 250 | 109.5 | 8.85 | 12.32 |
| NK | 302 | 0 | 250 | 109.7 | 9.05 | 12.12 |
| Adjoining NPK | 302 | 250 | 250 | 109.5 | 8.85 | 12.32 |

PLOT YIELDS

| Plots | Total Tons | Cane | Area | T. C. P. A. | Q. R. | T. S. P. A. |
|---------------|------------|------|-------|-------------|-------|-------------|
| 1N | 4.535 | | .0370 | 122.6 | | |
| 3N | 4.250 | | .0380 | 111.8 | | |
| 5N | 3.990 | | .0385 | 103.6 | | |
| 8N | 4.415 | | .0405 | 109.0 | | |
| 10N | 4.143 | | .0385 | 107.6 | | |
| 12N | 3.623 | | .0395 | 91.7 | | |
| 37N | 4.260 | | .0375 | 113.6 | | |
| 39N | 4.162 | | .0385 | 108.1 | | |
| 41N | 4.218 | | .0395 | 106.8 | | |
| 44N | 4.235 | | .0400 | 105.9 | | |
| 46N | 3.735 | | .0385 | 97.0 | | |
| 48N | 3.847 | | .0375 | 102.6 | | |
| 49N | 3.680 | | .0385 | 95.6 | | |
| 51N | 3.825 | | .0395 | 96.8 | | |
| 53N | 3.855 | | .0405 | 95.2 | | |
| 56N | 3.855 | | .0410 | 94.0 | | |
| 58N | 4.555 | | .0400 | 113.9 | | |
| 60N | 4.380 | | .0365 | 120.0 | | |
| Average ..... | .... |  | ..... | 105.2 | 9.06 | 11.61 |
| 13NK | 4.302 | | .0380 | 113.2 | | |
| 15NK | 4.335 | | .0385 | 112.6 | | |
| 17NK | 4.255 | | .0395 | 110.5 | | |
| 20NK | 4.162 | | .0375 | 111.0 | | |
| 22NK | 4.210 | | .0370 | 113.8 | | |
| 24NK | 4.055 | | .0385 | 105.3 | | |
| Average ..... | .... |  | ..... | 109.7 | 9.05 | 12.12 |
| 2NPK | 4.6875 | | .0385 | 121.7 | | |
| 4 | 4.0475 | | .0365 | 110.9 | | |
| 6 | 4.615 | | .0405 | 113.9 | | |
| 7 | 4.190 | | .0385 | 108.9 | | |
| 9 | 4.122 | | .0400 | 103.1 | | |
| 11 | 4.303 | | .0400 | 107.7 | | |
| 14 | 4.300 | | .0385 | 111.7 | | |
| 16 | 4.710 | | .0380 | 123.9 | | |
| 18 | 4.440 | | .0400 | 111.0 | | |
| 19 | 4.392 | | .0375 | 104.7 | | |
| 21 | 4.163 | | .0380 | 109.5 | | |
| 23 | 4.115 | | .0400 | 102.9 | | |
| 26 | 4.527 | | .0405 | 111.8 | | |
| 28 | 4.353 | | .0380 | 114.5 | | |

| Plots | Total Tons Cane | Area | T. C. P. A. | Q. R. | T. S. P. A. |
|---------------|-----------------|-------|-------------|-------|-------------|
| 30 | 4.362 | .0385 | 113.3 | | |
| 31 | 4.188 | .0375 | 111.7 | | |
| 33 | 4.152 | .0400 | 103.8 | | |
| 35 | 4.298 | .0410 | 104.8 | | |
| 38 | 4.177 | .0400 | 104.4 | | |
| 40 | 4.335 | .0380 | 114.1 | | |
| 42 | 4.440 | .0380 | 116.8 | | |
| 43 | 4.000 | .0375 | 106.7 | | |
| 45 | 3.985 | .0390 | 102.2 | | |
| 47 | 4.027 | .0410 | 98.2 | | |
| 50 | 4.258 | .0415 | 103.8 | | |
| 52 | 4.000 | .0400 | 100.0 | | |
| 54 | 4.070 | .0375 | 108.5 | | |
| 55 | 4.120 | .0380 | 108.4 | | |
| 57 | 4.352 | .0390 | 111.6 | | |
| 59 | 4.548 | .0415 | 109.6 | | |
| Average ..... | .... | ..... | 109.4 | 8.85 | 12.36 |
| 25NP | 4.195 | .0380 | 110.4 | | |
| 27 | 4.190 | .0410 | 102.2 | | |
| 29 | 4.310 | .0400 | 106.4 | | |
| 32 | 4.232 | .0405 | 104.5 | | |
| 34 | 4.175 | .0385 | 108.4 | | |
| 36 | 4.010 | .0395 | 102.8 | | |
| Average ..... | .... | ..... | 106.6 | 8.82 | 12.09 |

AVERAGE OF CARLOAD SAMPLES TAKEN AT O. S. CO. MILL

| Plots | Brix | Poln. | Purity | Q. R. |
|-------|------|-------|--------|-------|
| N | 17.5 | 14.85 | 84.95 | 9.06 |
| NP | 17.6 | 15.14 | 86.05 | 8.82 |
| NK | 17.2 | 14.81 | 85.51 | 9.05 |
| NPK | 17.5 | 14.99 | 85.50 | 8.85 |

Colloids and the Caking Quality of Raw Sugars

By A. L. HOLVEN

From the refiner's standpoint, caking and stickiness are the most seriously objectionable physical characteristics of certain Hawaiian raw sugars.

Caked sugars materially raise the cost of refining by increasing the labor involved in unloading steamers, warehousing, conveying, and cutting into process. The importance of this subject has led to a considerable amount of investigative work for the purpose of determining and eliminating the principal factors responsible for the caking of raw sugars. The fact that some raw sugars cake more readily than others led to the suggestion that the tendency of a sugar to become sticky and caked might be dependent on its colloid content, and in order

to settle this point W. R. McAllep, sugar technologist, Experiment Station, H. S. P. A., suggested that the question be investigated.

The investigation summarized in this report was therefore undertaken by the laboratory of the California and Hawaiian Sugar Refining Corporation, in order to study the possibility of a correlation between the colloid content and caking quality of raw sugars.

For the purposes of this study, a number of samples of raw sugars were simultaneously exposed to carefully controlled conditions of temperature and humidity in a constant humidity room in order to determine their comparative tendencies toward caking under the same atmospheric conditions. Comparison of these results with the colloid contents of the respective sugars has indicated that the amount of colloids has apparently no influence on the caking quality of the raw sugars, and the present report is issued merely for the purpose of summarizing these results as a matter of record.

SELECTION OF SAMPLES

In order that samples having a comparatively wide range of caking qualities might be studied, the selection of the samples used in these tests was based upon the relative amounts of each mark received in a caked condition at this refinery. Full Island bags of each of the following marks of raw sugar were segregated for these special tests:

| Mark | Plantation | Location | Agents |
|--------|------------------------|------------------|-----------------------------|
| 45 | Waimea Sugar Mill Co. | Waimea, Kauai | American Factors, Ltd. |
| Cir. L | Laupahoehoe Sugar Co. | Papaaloa, Hawaii | Theo. H. Davies & Co., Ltd. |
| 47 | Pioneer Mill Co. | Lahaina, Maui | American Factors, Ltd. |
| 14 | Olaa Sugar Co. | Olaa, Hawaii | American Factors, Ltd. |
| 1 | Hawn. Com. & Sugar Co. | Puunene, Maui | Alexander & Baldwin, Ltd. |
| 33 | Pepeekeo Sugar Co. | Pepeekeo, Hawaii | C. Brewer & Co., Ltd. |
| 49 | Oahu Sugar Co. | Waipahu, Oahu | American Factors, Ltd. |
| 32 | Onomea Sugar Co. | Papaikou, Hawaii | C. Brewer & Co., Ltd. |
| Cir. D | Hamakua Mill Co. | Paauilo, Hawaii | Theo. H. Davies & Co., Ltd. |
| 20 | Ewa Plantation Co. | Ewa, Oahu | Castle & Cooke, Ltd. |

DETERMINATION OF CAKING QUALITIES

These samples were placed in the constant humidity room and exposed to dehydrating conditions for a period of eleven days in order to accelerate their caking. Relative humidity was maintained at about 40 per cent, with a temperature of approximately 80° F. On the sixth day of exposure, the samples of Circle L and Circle D were caked, and within the ensuing three days the remaining eight samples caked.

Atmospheric conditions within the constant humidity room were then changed to 60 per cent relative humidity and an average temperature of 71° F. in order to produce conditions which would tend to resoften the caked sugars. These conditions were maintained for eight days and resulted in resoftening all except

Circle D and Circle L, which were finally softened by an additional exposure of three days to a relative humidity of about 68 per cent.

The relative caking and resoftening times of each of the above marks during this period of observation were substantially as follows:

CAKING QUALITIES OF VARIOUS MARKS

| Sample | Period For | |
|----------|------------|-------------|
| | Caking | Resoftening |
| Circle D | 6 Days | 11 Days |
| Circle L | 6½ " | 10 " |
| 45 | 7 " | 6 " |
| 32 | 7 " | 7 " |
| 14 | 7½ " | 8 " |
| 33 | 7½ " | 7 " |
| 47 | 8 " | 7 " |
| 1 | 8 " | 6 " |
| 20 | 8 " | 6 " |
| 49 | 9 " | 5 " |

While some raw sugars are naturally more resistant toward caking than others, it is obvious that under appropriate conditions of humidity and temperature practically any normal raw sugar will cake. It is of interest to note that, in general, the sugars which were the most readily caked were the most difficult to resoften, and vice versa.

ANALYSES OF SAMPLES

Deductions as to the relative amounts of colloids present in each of the above samples are based upon cataphoresis dye values, gum determinations, and surface tension depressions, as determined on each of the above samples. The following paragraphs briefly outline the significance of each of these determinations:

CATAPHORESIS DYE VALUES

Dye values were determined by cataphoresis titrations with the dye "Night Blue" and represent, in parts per 100,000, the amount of positively charged dye required to neutralize the negatively charged colloids in the raw sugar solution. The dye value is assumed to be approximately proportional to the amount of colloids. (For a more detailed consideration of this subject the reader is referred to the article entitled "Revised Directions for Operation of the Dye Test for Approximate Quantitative Determination of Colloidal Material in Sugar and Sugar Liquors," M. S. Badollet and H. S. Paine, *Planter and Sugar Manufacturer*, August 13, 1927.)

GUMS

Gums, as used in this report, refer to the alcohol insoluble organic matter. Previous investigations have indicated that gums may be regarded as indices of the approximate amounts of colloidal matter in raw sugars.

SURFACE TENSION DEPRESSIONS

Surface tensions were determined by means of the du Noüy apparatus on 20 per cent solutions of the raw sugars. This value has been expressed as surface tension depression, which is the difference between the surface tension of the sample and the surface tension of a pure sucrose solution of the same concentration. Surface tension depressions increase with increasing colloid contents.

The above analyses, as well as polarizations and moisture determinations, were made on each of the above samples before the start of the tests, after all raws were caked, and after all raws were resoftened. The results of these tests are shown in the following tabulation:

ANALYSES OF RAW SUGAR SAMPLES

| | Mark | Mark | Mark | Mark | Mark | Mark | Mark | Mark | Mark | Mark |
|------------------------|--------|------------|--------|--------|------------|------------|------------|------------|--------|--------|
| | Cir. D | Cir. L | 45 | 32 | 14 | 7 1/2 Days | 7 1/2 Days | 7 1/2 Days | 8 Days | 8 Days |
| Caking Time | 6 Days | 6 1/2 Days | 7 Days | 7 Days | 7 1/2 Days | 7 1/2 Days | 7 1/2 Days | 7 1/2 Days | 8 Days | 8 Days |
| Resoftening Time | 11 " | 10 " | 6 " | 6 " | 8 " | 7 " | 7 " | 7 " | 6 " | 6 " |

Original Free Running Sugars

| | | | | | | | | | | |
|----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direct Polimization | 97.2 | 97.87 | 98.10 | 98.85 | 98.50 | 97.45 | 97.42 | 97.90 | 97.35 | 98.40 |
| Moisture | 0.49 | 0.33 | 0.26 | 0.13 | 0.19 | 0.39 | 0.33 | 0.25 | 0.30 | 0.16 |
| Purity | 97.68 | 98.19 | 98.36 | 98.98 | 98.69 | 97.83 | 97.74 | 98.15 | 97.64 | 98.56 |
| Deterioration Factor | 0.18 | 0.15 | 0.14 | 0.11 | 0.13 | 0.15 | 0.13 | 0.12 | 0.11 | 0.10 |
| Surface Tension Depression | 22.2 | 18.6 | 15.4 | 16.3 | 17.6 | 17.3 | 16.6 | 16.6 | 15.4 | 14.7 |
| Per Cent Gums | 0.80 | 0.34 | 0.25 | 0.18 | 0.27 | 0.31 | 0.40 | 0.24 | 0.25 | 0.26 |
| Dye Value | 235 | 160 | 190 | 150 | 219 | 175 | 223 | 263 | 170 | 110 |

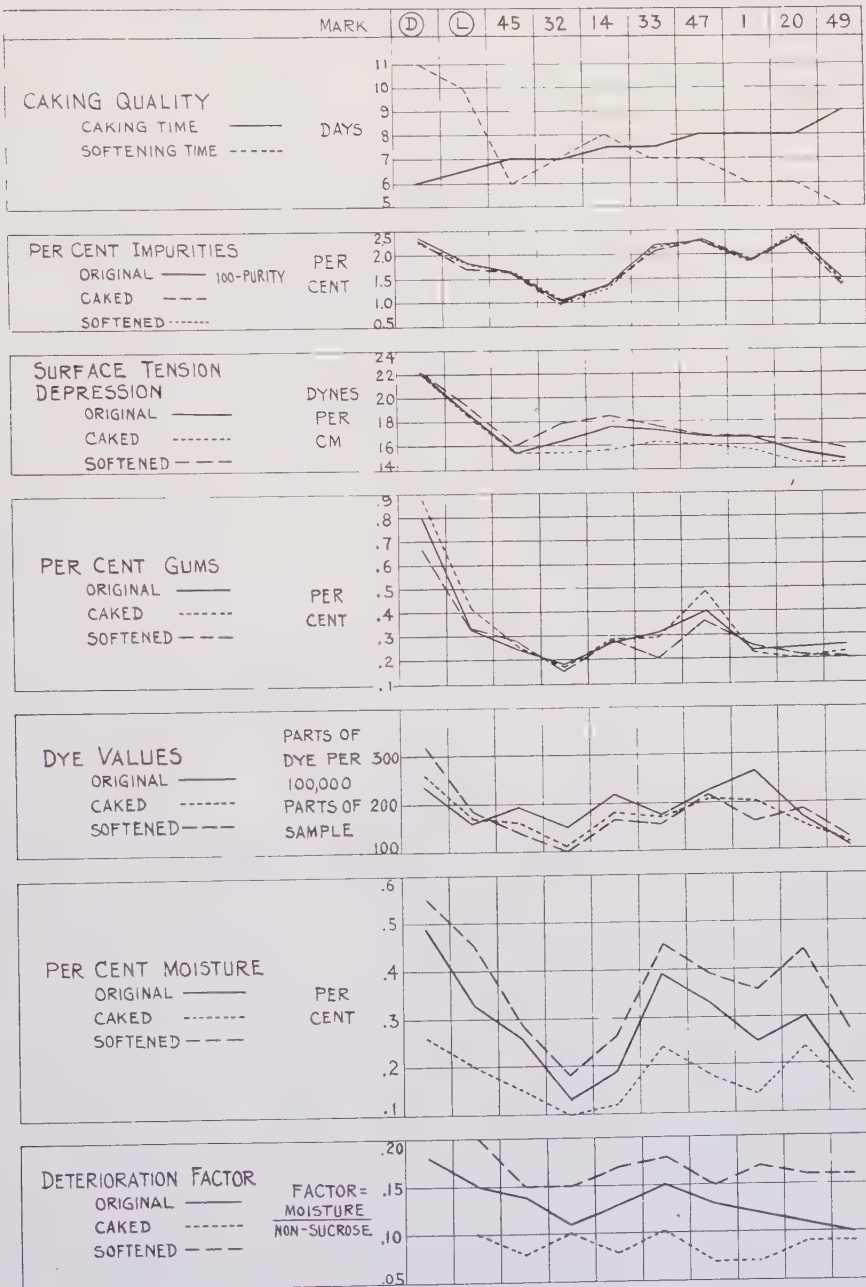
Caked Sugars

| | | | | | | | | | | |
|----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direct Polimization | 97.43 | 98.08 | 98.20 | 98.95 | 98.57 | 97.69 | 97.55 | 97.99 | 97.44 | 98.48 |
| Moisture | 0.26 | 0.20 | 0.15 | 0.10 | 0.12 | 0.24 | 0.18 | 0.14 | 0.24 | 0.14 |
| Purity | 97.68 | 98.28 | 98.35 | 99.05 | 98.69 | 97.93 | 97.73 | 98.13 | 97.67 | 98.62 |
| Deterioration Factor | 0.10 | 0.10 | 0.08 | 0.10 | 0.08 | 0.10 | 0.07 | 0.07 | 0.09 | 0.09 |
| Surface Tension Depression | 22.2 | 18.6 | 15.4 | 15.4 | 15.6 | 16.3 | 16.0 | 15.6 | 14.4 | 14.4 |
| Per Cent Gums | 0.88 | 0.43 | 0.26 | 0.17 | 0.28 | 0.29 | 0.48 | 0.23 | 0.20 | 0.23 |
| Dye Value | 260 | 170 | 160 | 110 | 180 | 173 | 210 | 200 | 155 | 115 |

Resoftened Sugars

| | | | | | | | | | | |
|----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Direct Polimization | 97.18 | 97.76 | 98.05 | 98.80 | 98.47 | 97.45 | 97.39 | 97.84 | 97.17 | 98.32 |
| Moisture | 0.55 | 0.45 | 0.29 | 0.18 | 0.26 | 0.45 | 0.39 | 0.36 | 0.44 | 0.27 |
| Purity | 97.72 | 98.20 | 98.34 | 98.98 | 98.73 | 97.89 | 97.77 | 98.19 | 97.60 | 98.59 |
| Deterioration Factor | 0.20 | 0.20 | 0.15 | 0.15 | 0.17 | 0.18 | 0.15 | 0.17 | 0.16 | 0.16 |
| Surface Tension Depression | 22.0 | 19.3 | 16.0 | 17.8 | 18.5 | 17.5 | 16.7 | 16.6 | 16.4 | 15.7 |
| Per Cent Gums | 0.67 | 0.34 | 0.27 | 0.15 | 0.28 | 0.20 | 0.36 | 0.25 | 0.22 | 0.21 |
| Dye Value | 320 | 185 | 140 | 100 | 165 | 155 | 215 | 160 | 185 | 125 |

COMPARISON OF CAKING QUALITIES WITH OTHER CHARACTERISTICS OF RAW SUGARS



In the following tabulation, the sugars are arranged according to increasing colloid contents as indicated by the above determinations on the final samples, and these values are compared with their tendency toward caking.

COMPARISON BETWEEN COLLOID CONTENT AND CAKING QUALITY

| Mark | Dye Value | Per Cent Gums | Surface Tension* | Days Required to | |
|--------|-----------|---------------|--------------------------------------|------------------|----------|
| | | | Depression (Dynes per Centimeter) | Cake | Resoften |
| 32 | 100 | .15 | 17.8 | 7 | 7 |
| 49 | 125 | .21 | 15.7 | 9 | 5 |
| 45 | 140 | .27 | 16.0 | 7 | 6 |
| 33 | 155 | .20 | 17.5 | 7½ | 7 |
| 1 | 160 | .25 | 16.6 | 8 | 6 |
| 14 | 165 | .28 | 18.5 | 7½ | 8 |
| 20 | 185 | .22 | 16.4 | 8 | 6 |
| Cir. L | 185 | .34 | 19.3 | 6½ | 10 |
| 47 | 215 | .36 | 16.7 | 8 | 7 |
| Cir. D | 320 | .67 | 22.0 | 6 | 11 |

(* Note: Surface tension depressions are usually regarded as indices of the relative amounts of emulsoid colloids, but in a number of instances these results are inconsistent with dye values and per cent gums. Therefore, the latter determinations are to be accepted as the more reliable indications.)

It is of interest to note that Mark Circle D, which had the highest colloid content caked the most readily, while Mark 49, which had next to the lowest colloid content was the most resistant toward caking. While these facts might indicate that caking was more or less dependent on colloid content, this supposition is not confirmed by the general trend of the other samples and it is believed, therefore, that the apparent relationship was merely coincidental.

As it had been noted that some of the Mark 49 received on February 23 was partially caked (i. e., sticky), it was believed that a comparison of the relative amounts of colloids in the sticky and normal Mark 49 sugars might yield further information on this problem. The results of comparative determinations on reserve samples of these sugars are as follows:

COMPARISON BETWEEN NORMAL AND STICKY

Mark 49—Received February 23

| | Normal Raw | Sticky Raw |
|---------------------------------|------------|------------|
| Dye Value | 140 | 140 |
| Per Cent Gums..... | .26 | .19 |
| Surface Tension Depression..... | 19.2 | 16.0 |

While the dye values are identical, both the gums and surface tension determinations indicate that the sticky and caked raw actually contained a relatively smaller amount of colloids than the normal raw.

The results of these tests have indicated that there is no correlation between colloid content and caking quality.

As caking is logically being regarded as a cementing action resulting from crystallization in the molasses film, it is of interest to compare the caking quality of these sugars with their deterioration factors (relation between moisture content and total non-sucrose).

| Mark | Caking Time | | Resoftening Time | Purity | Moisture in Original Sample Per Cent | Deterioration Factor |
|--------|-------------|------|------------------|--------|--------------------------------------|----------------------|
| Cir. D | 6 | Days | 11 Days | 97.7 | 0.49 | 0.18 |
| Cir. L | 6½ | “ | 10 “ | 98.2 | 0.33 | 0.15 |
| 45 | 7 | “ | 6 “ | 98.4 | 0.26 | 0.14 |
| 32 | 7 | “ | 7 “ | 99.0 | 0.13 | 0.11 |
| 14 | 7½ | “ | 8 “ | 98.7 | 0.19 | 0.13 |
| 33 | 7½ | “ | 7 “ | 97.8 | 0.39 | 0.15 |
| 47 | 8 | “ | 7 “ | 97.7 | 0.33 | 0.13 |
| 1 | 8 | “ | 6 “ | 98.2 | 0.25 | 0.12 |
| 20 | 8 | “ | 6 “ | 97.6 | 0.30 | 0.11 |
| 49 | 9 | “ | 5 “ | 98.6 | 0.16 | 0.10 |

The above comparison indicates that there is no direct relationship between caking quality and either moisture or purity considered as separate factors. These results do indicate, however, that in general sugars with high deterioration factors are more readily caked than sugars with low deterioration factors. It is quite probable that the more rapid caking of sugars having high deterioration factors is due to the presence of a relatively greater quantity of syrup, which, upon evaporation, tends to cement the sugar crystals to a caked mass. Size of grain is another factor which may have more or less influence on the caking qualities of raw sugars.

The apparent relationship between caking quality and deterioration factor is in accord with a theory advanced by G. W. Aljian in the Quarterly Report for Raw Sugars Received at Crockett from the Hawaiian Islands—Second Quarter of 1926, March 27 to July 31, quoted as follows:

Caked and sticky raws received on steamers are classified in two groups—those received in the boiler hatches of the steamers and those received in all other hatches. Sticking or caking of the raws in the boiler hatches is a result of the high temperature of the atmosphere drying out the sugar during transportation. Raws from all plantations become sticky or caked when exposed to this condition. Caked and sticky sugars from non-boiler hatches must, however, be charged to the method of manufacturing or storing of the sugar prior to its delivery to the steamers.

The theory has been advanced that sticking and caking of raw sugar are dependent chiefly on the dryness of the syrup film surrounding the crystal. When this syrup is relatively dry, the sugar may be considered to become sticky because of the corresponding relatively high viscosity of the syrup. If this is the cause, it is reasonable to expect that the sugar may cake in a short time after storage when the voids between the crystals disappear through compression.

On the other hand, when the syrup surrounding the crystal is relatively wet through excessive or prolonged washing and poor drying, it is reasonable to expect that this syrup is relatively high in purity as a result of dissolving sucrose by the moisture enveloping the sugar crystal. It is also reasonable to expect that this syrup, being less hygroscopic because of its relatively small percentage of non-sugars, readily loses moisture when exposed to the atmosphere. When such drying takes place, the sugar is apt to cake due to a secondary crystallization that causes a cementing action to unite the crystals into a compact mass.

CONCLUSION

In briefly summarizing the results of this investigation, it is concluded that, apparently, colloids have no direct influence on the caking quality of raw sugars.

Caking quality does, however, appear to be more or less dependent on the relation between moisture and total non-sugars. As such, it is a partial substantiation of the theory that caking may be due to the cementing action caused by evaporation from a syrup film which, because of its high purity, is less hygroscopic than the syrup films of lower purity, which are associated with sugars more resistant toward caking.

These results have also confirmed the fact that under sufficiently dehydrating conditions, practically any raw sugar will cake, and the sugars which cake most readily are the most difficult to resoften, and vice versa.

In conclusion it may be stated that from present indications it is believed that the caking of raw sugars is a function of both the hygroscopic nature of the syrup and the relative humidity of the surrounding atmosphere.

Amounts of the Less Essential Plant Nutrients Present in the New Concentrated Fertilizers

By G. R. STEWART and F. R. VAN BROCKLIN

During the past year Hansson* carried out an investigation of the less essential plant nutrients present in the materials at that time entering into our mixed fertilizers. In his discussion of this work, Hansson referred to the growing volume of evidence which is being obtained, regarding the needs of many crops for these less usual nutrients. The current reports appearing from a number of the American and European experiment stations emphasize the importance of the rarer nutrients for crop plants and orchard trees. The amounts of the less usual nutrient elements required by any plant are very small. At the same time we have little information as to the supply of copper, manganese, boron, zinc, fluorine, bromine, iodine, aluminum and arsenic furnished by the average agricultural soil. Hence it is of interest to know the amounts of the rarer nutrients supplied by the fertilizers which are put on the land.

The materials examined by Hansson included, nitrate of potash, nitrate of soda, muriate of potash, both of German and American origin, sulphate of potash, sulphate of ammonia, superphosphate, bone meal and dried blood.

At the present time a number of new concentrated materials are being employed to manufacture more concentrated mixed fertilizers. It, therefore, appeared to be desirable to make an examination of these new synthetic products in order to determine whether they supplied any of the less usual ingredients. The results

* Some Unusual Constituents Present in Common Fertilizers. *Hawaiian Planters' Record*, Vol. XXXII, pp. 342-346, 1928.

of this examination are given in the accompanying table. Before discussing the results of the analyses, a brief description of these newer fertilizers may be of interest.

CALCIUM UREA OR "CALUREA"

Calurea is a mixture of equal parts of calcium nitrate and urea. Shipments which have been received in Hawaii have contained 34.3 per cent of total nitrogen. This nitrogen was divided into 6.5 per cent nitrate nitrogen, 0.5 per cent ammonia nitrogen and 27.3 per cent amid nitrogen.

NITROPHOSKA I. G.

This material is a mixed fertilizer which contains a high percentage of nitrogen, phosphoric acid and potash. A number of different formulae of this fertilizer are being manufactured abroad. At the present time formula No. 3 is offered for sale in the United States. This consists of 15.6 per cent total nitrogen, 32 per cent phosphoric acid and 16 per cent of potash. Nitrophoska is being used principally as the basis for high-analysis mixed fertilizers by the addition of nitrogen, phosphates or potash salts, to suit the needs of special crops in different districts.

LEUNA SALTPETRE

This salt is a mixture of equal parts of ammonium sulphate and ammonium nitrate, which are combined while in solution and then crystallized out into a homogeneous compound. The nitrogen content of the leuna saltpetre is approximately 26 per cent, of which 19 per cent is ammonia nitrogen and 7 per cent nitrate nitrogen.

NITRATE OF LIME

The new nitrate of lime, which is largely imported from Germany, is a white crystalline product to which approximately 4 per cent of ammonium nitrate has been added, to aid in crystallization and to increase the nitrogen content. The nitrogen content of this new product is about 15.5 per cent.

TREBLE SUPERPHOSPHATE

This is a high-grade phosphate product, which is made by first treating a low grade of phosphate rock with an excess of dilute sulphuric acid, until the greater portion of the phosphate originally contained in the rock is dissolved in the sulphuric acid. The mixture of sulphuric and phosphoric acids is then separated from the rock residue by filtration and is used to convert a high-grade rock phosphate into a superphosphate. Because the sulphuric acid employed for this final treatment of the phosphate rock already contains phosphoric acid, the resulting superphosphate contains more than double the usual content found in ordinary superphosphates. The shipments of double and treble superphosphate, commonly received in Hawaii, range in phosphate content from 45 to 52 per cent P_2O_5 .

AMMONIUM PHOSPHATE

Several formulae of ammonium phosphate are now sold on the American market. These materials are all compounds of synthetic ammonia and of phosphoric acid, which is generally prepared from the lower grades of phosphate rock. Two formulae of ammonium phosphate have been widely sold under the trade-name of "Ammophos". One grade of this product contains 16.54 per cent nitrogen and 20 per cent phosphoric acid. The other formula carries 10.7 per cent nitrogen and 48 per cent phosphoric acid.

AMMONIUM NITRATE

Ammonium nitrate contains approximately 34.5 to 35 per cent nitrogen. This nitrogen is present as equal amounts of ammonia and nitrate nitrogen. Ammonium nitrate has a considerable industrial use as well as its application as a fertilizer. There is now an appreciable tariff upon the foreign product, so that this salt will probably not find a large market as a fertilizer until it is made on a larger scale in the United States.

UREA

This product is the most concentrated nitrogenous fertilizer which has been produced up to this time. It contains 46 per cent of amid nitrogen, which is chemically classed as being equal to the organic nitrogen derived from slaughter house by-products. Urea has not been used to any great extent on a commercial scale, as it is a comparatively new fertilizer material.

RARE CONSTITUENTS FOUND IN THE FERTILIZERS

In Table I, the amounts of manganese, copper, zinc, boron, iodine, bromine and fluorine found in the new products are listed on a percentage basis. In order that a comparison may be made of the results previously obtained by Hansson we have reprinted his analytical results upon the older fertilizer materials as Table II. The following comparisons may be made between the newer and older fertilizers.

MANGANESE

Hansson found traces of manganese in nitrate of potash and German muriate of potash and small but determinable amounts of manganese in nitrate of soda and bone meal. We now find that the newer forms of fertilizer contain larger amounts of manganese than were found in the older products. Those materials in which no manganese was found were ammonium nitrate, urea and calcium urea.

COPPER

All the newer forms of fertilizer contain minute quantities of copper. The older materials containing copper were sulphate of ammonia, bone meal and dried blood.

ZINC

All the new concentrates carry small amounts of zinc. Of the older materials only sulphate of ammonia contained any zinc.

BORON

None of the new concentrates contained any traces of boron. In the older materials boron was found in small amounts in nitrate of potash, American muriate of potash, nitrate of soda and sulphate of potash.

IODINE

None of the new forms of fertilizer were found to contain iodine, either as free iodine or as the iodate. In the older products traces of free iodine were found to be present in nitrate of potash, muriate of potash, nitrate of soda and in superphosphate. Iodine combined as an iodate was present in nitrate of potash, American muriate of potash and in nitrate of soda.

BROMINE

Bromine was found in only one of the newer materials, that is in nitrophoska. In the older materials, bromine was found in nitrate of potash and in both German and American muriate of potash.

FLUORINE

Traces of fluorine were found in treble superphosphate and ammonium phosphate of the new products. Fluorine was found in the older materials in sulphate of ammonia and superphosphate.

SUMMARY

To summarize the above pieces of work, it may be pointed out that the new concentrated materials examined at this time contain more manganese, copper and zinc than the older forms of fertilizer materials.

None of the new products supply any boron or iodine. Fluorine is present in traces in materials derived from several of the phosphate rocks and is found in approximately equal amounts in the older and newer forms of phosphates.

Work is now under way in this laboratory to determine which of these less usual nutrients are essential to the growth of the cane plant. The amounts of the rarer nutrients required for any crop so far investigated have been found to be exceedingly small. It must also be emphasized that an excess of these rarer plant nutrients is in most cases extremely toxic for plant growth. None of the fertilizer materials examined by Hansson or the writers appears to contain excessive amounts of the rarer ingredients. It would appear to be perfectly possible to obtain small amounts of the more important of the rare nutrients in mixed fertilizers, which are largely made from the new concentrated materials, if American muriate of potash is used as a source of potash. This potash salt carries a minute amount of boron, iodine and bromine, which are lacking in the new concentrated materials.

We have also work under way to try to determine the presence of the less usual elements in a number of our typical plantation soils. These current investigations will enable us to state how much importance should be given to the presence or absence of the rarer nutrients in estimating the probable value of a fertilizer.

TABLE I
ANALYTICAL RESULTS

Percentage of Some of the Unusual Constituents in the Concentrated Fertilizers

| Fertilizer Material | Per Cent Manganese as MnO | Per Cent Copper as Cu | Per Cent Zinc as Zn | Per Cent Boron as Na ₂ B ₄ O ₇ | Per Cent Iodine as Iodide I | Per Cent Iodine as Iodate I | Per Cent Bromine as Bromide Br | Per Cent Bromine as Bromate Br | Per Cent Fluorine as Fluoride Fl |
|----------------------------------|---------------------------------|-----------------------------|---------------------------|---|-----------------------------------|-----------------------------------|--------------------------------------|--------------------------------------|--|
| Calcium urea | None | 0.0016 | 0.0024 | None | None | None | None | None | None |
| Nitrophoska I G..... | 0.0139 | 0.0074 | 0.0040 | None | None | None | 0.0144 | None | None |
| Leuna saltpetre | 0.0068 | 0.0029 | 0.0024 | None | None | None | None | None | None |
| Nitrate of Lime..... | 0.0114 | 0.0024 | 0.0024 | None | None | None | None | None | None |
| Treble superphosphate | 0.0123 | 0.0220 | 0.014 | None | None | None | None | None | Trace |
| Ammonium phosphate (Anaconda) .. | 0.0105 | 0.0340 | 0.032 | None | None | None | None | None | Slight trace |
| Ammonium phosphate (16.4% N) ... | 0.0121 | 0.0190 | 0.030 | None | None | None | None | None | Trace |
| Ammonium phosphate (10.7% N) ... | 0.0164 | 0.0091 | 0.014 | None | None | None | None | None | Trace |
| Ammonium nitrate | None | 0.0032 | 0.012 | None | None | None | None | None | None |
| Urea | None | 0.0024 | 0.020 | None | None | None | None | None | None |

TABLE II

ANALYTICAL RESULTS

Percentage of Some of the Unusual Constituents in the Common Fertilizer Materials

| Fertilizer Material | Per Cent Manganese as MnO | Per Cent Copper as Cu | Per Cent Zinc as Zn | Per Cent Boron as Na ₂ B ₄ O ₇ | Per Cent Iodine as Iodide I | Per Cent Iodine as Iodate I | Per Cent Bromine as Bromide Br | Per Cent Bromine as Bromate Br | Per Cent Fluorine as Fluoride Fl |
|-----------------------------------|---------------------------------|-----------------------------|---------------------------|---|-----------------------------------|-----------------------------------|--------------------------------------|--------------------------------------|--|
| Nitrate of potash..... | Trace | None | None | 0.404 | Trace | .0240 | 0.0012 | None | None |
| Muriate of potash (German)..... | Trace | None | None | Trace | Trace | None | 0.094 | None | None |
| Muriate of potash (American)..... | None | None | None | 0.180 | Trace | .0052 | 0.796 | None | None |
| Nitrate of soda..... | .00046 | None | None | 0.095 | Trace | .0104 | Trace | None | None |
| Sulphate of ammonia..... | None | .00038 | .035 | Trace | None | None | None | None | 0.145 |
| Sulphate of potash..... | None | None | None | .0023 | Trace | None | Trace | None | None |
| Superphosphate | None | None | None | None | None | None | None | None | Approx. 0.50 |
| Bone meal | .0036 | .00043 | None | Trace | None | None | None | None | None |
| Dried blood | None | .00042 | Trace | Trace | None | None | None | None | None |

The Availability of Potash*

By W. T. McGEORGE

In the progress and development of our knowledge of soil fertility, a great deal of time and effort has been expended in searching for definitely reliable guides to soil management. As one phase of this problem, some means of estimating plant food availability would admittedly be of infinite value. While soil chemists have devoted much effort to this phase of soil research, their extensive studies have thus far evolved only empirical methods of limited application. As a matter of fact some students of soil fertility question even a limited application.

It is recognized that a determination of the total potassium in the soil, which can be very accurately made, serves only as an inventory of the reserve supply which may or may not, at some future time, become available to the plant. Only after the elements are dissolved in the soil solution do they become directly subject to assimilation. Furthermore, the amounts of plant food elements usually found in the soil solution represent only an extremely small percentage of that present in the soil. In addition to this, the concentration of the soil solution fluctuates greatly from day to day, as does also the ratio of the various elements present in solution and necessary in plant nutrition. This fluctuation is brought about by such agencies as rainfall, temperature, and draught of the crop, as well as a number of other factors. It is evident, that like the determination of total potassium in the soil, the analysis of the soil solution, or a water extract, is also of limited value.

It is believed that there are rather definitely defined periods in the growth of a crop, during which its plant food requirements will fluctuate greatly. Therefore, the availability or rapidity with which a necessary element will enter the soil solution is recognized as a controlling factor in crop performance. On this basis it may readily be seen why so much time has been devoted to methods of determining the available plant food in soils.

Recognizing the difficulty or even impossibility of attaching any sound, theoretical interpretation to a soil analysis, in which any reagent is employed as solvent, interpretations have been made largely empirical, as already stated. Such dilute acids as 1 per cent citric acid, N/5 nitric acid, as well as several others, have been extensively studied. On the basis that plants feed through the medium of a slight acidity within the feeding zone of the root tip, created by means of a secretion of carbon dioxide, the use of these weak acid solvents has, in the main, been an attempt to simulate root activity. The value of weak acid solvents for potassium, and their application to soil management on our island plantations, has been treated in Experiment Station, H. S. P. A., Bulletin 48 (4), so there is no need to go into further detail here. Suffice it to say that on the whole 1 per cent citric acid, as a measure of available potassium, interpretations being made on the basis

* Additional study and discussion on potassium availability is presented as a part of an accompanying article on Electrodialysis of Hawaiian Soils.

of data obtained from soils of known field performance, has found extensive and reliable application.

During the course of an intensive study of the low fertility of Kilauea soils, the availability of potash has received a commanding attention. The appearance of the plants in the field is indicative of potash starvation. There is a premature death of the lower leaves which begins with a "marginal firing", that is, a progressive drying from the leaf margin and leaf tip inwards and, in some cases, a deterioration or even premature death of the stalk. A rapid deterioration of cane following the period of tassel is characteristic of Kilauea-grown cane. Among the physiological properties of potash the greater resistance which it imparts to a crop against adverse climatic conditions is outstanding. Potash-deficient crops are usually the first to suffer in a bad season or in cold weather. In view of this well-known property of potash, coupled with our observations at Kilauea, it is not unreasonable to suppose that cane grown under the climatic conditions at Kilauea may have a higher potash requirement. Thus far our investigations have only touched upon the cane plant, soil studies having occupied our entire time. The above reference to the properties of potash is merely included as bearing upon the relation of potash to our problem and because our study is now being centered upon the plant. The soil studies have given much of value and are practically completed.

FIELD EXPERIMENTS

It has generally been observed in field experiments at Kilauea that a variable response to potash will often appear during the early stages of growth only to completely, or almost completely, disappear at harvest. This may often be true where as much as 1,000 to 1,500 pounds potash (K_2O) per acre has been added, as was shown by Experiment 63 in Field 28.

SOIL SURVEY

The soil survey of Kilauea plantation showed a good supply of potash, the total potash varying from 10,000 to 36,000 pounds K_2O per acre foot, but as measured by 1 per cent citric acid, the availability is very low. At our request, L. D. Larsen, manager of Kilauea plantation, kindly submitted a classification of all the

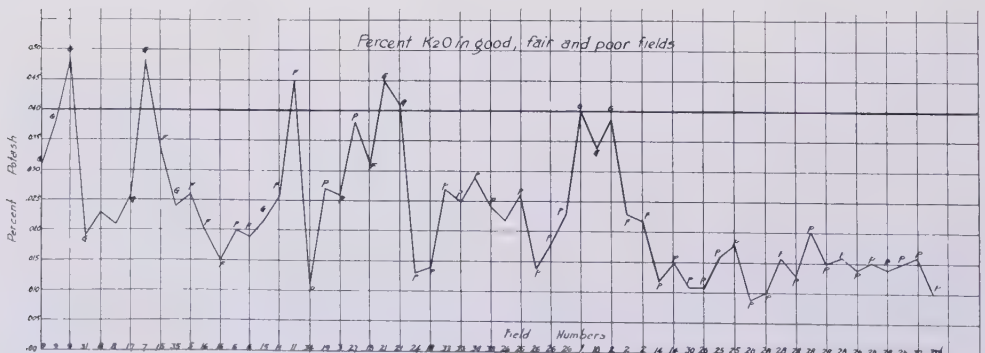


Fig. 1

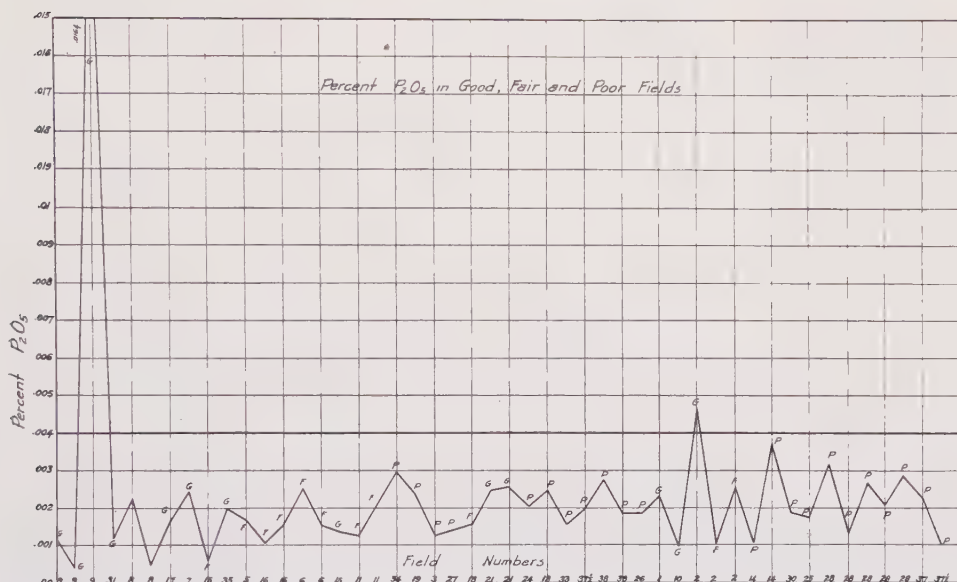


Fig. 2

plantation fields as good, fair or poor, according to yield. The availability of potash was then plotted and is shown graphically in Fig. 1. In this graph there is shown the per cent K_2O soluble in 1 per cent citric acid, with each point on the curve representing a field and designated as good, fair or poor. While there are a few exceptions, it will be noted that on the whole the good fields are characterized by higher potash availability, and the poor fields by low availability. As a matter of comparison, a similar graph is presented as Fig. 2, showing the relation between available phosphate and good, fair and poor classification. While it is evident that phosphate, too, is of very low availability, with the exception of two fields, all are uniformly low regardless of crop performance.

FIXATION OF POTASH

From the soil analyses one would expect the poor fields to give a notable response to potash fertilization, since in other island districts such low potash soils respond readily. The failure of Kilauea soils to give more than a slight response where any response at all is obtained, brings up the question of the factors associated with the low availability. We were especially interested in learning if, after fertilization, the potash became fixed in a form no longer available to the plant and, if so, the nature of this absorption.

In character, the Kilauea soils, notably the mauka fields, are possessed of a highly dispersed yellow colloidal clay. The clay fraction of a soil is actively associated with the fixation of potash and is, for this reason, often referred to as the absorbing complex. While the identity of this absorbing complex has not been definitely established, it is apparently of the class of silicates known as zeolites, and this latter term, zeolite potash, will be used in referring to the absorbed potash throughout this paper. The bases, such as lime, magnesium, potassium and sodium,

which are held by the zeolite, are also often referred to as replaceable bases because of the fact that they are present in a very reactive form and, under certain conditions, the absorbed bases will be exchanged for other bases present in the soil solution or those added in fertilizer or irrigation water. In view of the great progress which has been made in the study of base fixation in soils since the publication of Bulletin 48, we have investigated the relation of the absorbed bases to potash availability in the Kilauea soils.

The presence of zeolites in soils was first recognized at least fifty years ago and to these compounds was attributed the fixing property of the soil. Their real function, their properties and the nature of their reactions, however, has only recently come to be understood and appreciated. One result of this has been a more definite understanding of the availability of potassium. This element is present in the soil solution only in small amounts, that is, as compared to calcium, magnesium and sodium. The potassium present in the soil solution, at any one time, is often considered as practically negligible. This has led to the suggestion that plants are largely dependent upon zeolite potassium for their nutrition. The question of the availability of zeolite potassium is, therefore, of paramount importance. Theoretically, potassium zeolite will hydrolyze and ionize in contact with water and thus supply soluble potassium to the plant, and Breazeale(2) has demonstrated that it does function in this manner. He has also shown that the reaction is enhanced by the presence of the soluble salt of another base. On the other hand, while some other soluble base is usually present in the soil solution this is not entirely necessary, as he has further demonstrated, because potassium zeolite will hydrolyze and ionize in water and yield, at equilibrium, a solution containing as much as 30 parts per million potassium.

EXPERIMENTAL

A number of good, fair, and poor fields at Kilauea were selected and samples of surface soil representing, the top foot, and subsoil, representing the second foot, were taken. In addition a sample from the Hilo Sugar Company, representing a soil that responds to potash, one from Ewa plantation which also responds to potash, and one each from Ewa and the Waipio substation representing soils which do not respond to potash. A description of these soils follows, the soils marked (a) being surface soils, and those marked (b) subsoils:

- 2a, 2b—greyish brown silty clay loam—a fair field.
- 5a, 5b—brownish yellow silty clay loam—a fair field.
- 7a, 7b—red to brown silty clay loam—a good field.
- 11a, 11b—red clay loam—a fair field.
- 12½a, 12½b—reddish yellow clay loam—poor field.
- 14a, 14b—yellowish brown silty clay loam—poor field.
- 16a, 16b—yellowish brown silt loam—good field.
- 21a, 21b—red silty clay loam—good field.
- 24a, 24b—yellow clay loam—poor field.
- 28a, 28b—brownish yellow silty clay loam—poor field.
- 33a, 33b—yellow clay loam—poor field.
- 37a, 37b—yellow brownish clay loam—poor field.

Most of the subsoils at Kilauea merge off to a pale reddish yellow color and somewhat heavier texture:

H—yellow gravelly loam—Hilo Sugar Company—responds to potash.
 V—brown silty clay loam—Waipio substation—no response to potash.
 VK—same as V, but from the potash plot of Experiment V.
 11—clay soil—Ewa Plantation Company—responds to potash.
 19B—red clay loam—Ewa Plantation Company—no response to potash.

2827—Experiment 63, Kilauea, Plot 3B, 1,500 lbs. K_2O per acre.
 2828—Experiment 63, Kilauea, Plot 1X, no potash, near Plot 3B.
 2829—Experiment 63, Kilauea, Plot 4X, no potash, adjacent to Plot 3B.
 2830—Obs. test 5, Kilauea, Plot C1, no potash.
 2831—Obs. test 5, Kilauea, Plot E3, 600 lbs. K_2O per acre.
 2835—Experiment 68, Kilauea, Plot 16X, no potash.
 2836—Experiment 68, Kilauea, Plot 15B, 1,000 lbs. K_2O per acre.

In Experiment 63 there was a slight response in plot 3B during the early stages, and a slight response at harvest in Experiment 68. The former is located in Field 28 and the latter in Field 25, both poor fields.

In these soils the bases calcium, magnesium, sodium and potassium were determined by extraction with strong hydrochloric acid, with 1 per cent citric acid, and the zeolite bases determined by replacement, using both normal ammonium chloride and tenth-normal barium chloride solutions. The zeolite hydrogen was determined by replacement with neutral normal solution of barium acetate, and the leachate titrated with N/10 barium hydrate, using the quinhydrone electrode. The replacement capacity was determined by leaching the soil with N/1 neutral ammonium acetate, washing free of ammonium with methyl alcohol, and determining the ammonium fixed by the soil. The results are given in Table I. In Table II the zeolite bases are given on a milligram equivalent basis.

Calcium: The citrate soluble calcium agrees fairly well with the zeolite calcium in the Kilauea soils, but less so in those from Hilo, Waipio and Ewa. In all cases the zeolite calcium is consistently higher, showing that 1 per cent citric acid will not, in a single extraction, dissolve all the zeolite calcium. There is noted a wide variation in the ratio of zeolite calcium to that soluble in strong hydrochloric acid and, in several cases, as high as 80-90 per cent of the hydrochloric acid soluble calcium is in the form of zeolite. In all cases the zeolite calcium is notably less in the subsoil than in the surface soil. There is no relation between the form of calcium present in the soil and the good, fair and poor classifications of fields; nor is there any relation between the citric soluble and zeolite potassium and the calcium. The same holds true when the calcium is figured on a milliequivalent basis, as shown in Table II.

Magnesium: With the exception of two fields, 28 and 33, the magnesium soluble in 1 per cent citric acid is greater than the zeolite magnesium. This does not hold true for the soils from Hilo and Ewa. The ratio of magnesium soluble in strong hydrochloric acid to zeolite magnesium is much lower than for calcium, but apparently this is of no important significance. Also, the magnesium determinations do not show any relation to the good, fair and poor classifications. While the zeolite magnesium is lower in the Kilauea soils than in those from

Waipio and Ewa, the Hilo soil, which gives a ready response to potassium, is, like the Kilauea soils, low in zeolite magnesium. Like calcium, the subsoils are all markedly lower in zeolite magnesium than are the surface soils.

Sodium: The sodium soluble in 1 per cent citric acid is a great deal less than that present as zeolite in the Kilauea and Hilo soils, while with the Ewa and Waipio soils there is rather close agreement. The ratio of sodium soluble in strong hydrochloric acid to that present as zeolite shows that this element is largely present in forms other than the zeolite and is, therefore, less available. Strange to say, there is a rather close agreement between the zeolite sodium in the soil and subsoil, which is in direct contrast to the calcium and magnesium. On the whole, the data give rather convincing evidence that the zeolite sodium is fixed more strongly in the Kilauea soils than in the more fertile soils such as the Ewa and Waipio types.

Hydrogen: The hydrogen combined with the zeolite to form soil acidity fluctuates over a wide range, probably due to the lime applications which have been made during years past. There is no consistency between soils and subsoils. In some cases the subsoils contain less zeolite hydrogen than the surface soils.

Potassium: Without a single exception the zeolite potassium, like the zeolite sodium, is greater than the citric soluble potassium. On the other hand, there is a close agreement between the zeolite potassium and that soluble in 1 per cent citric acid in the more fertile soils taken from Ewa, Waipio and Hilo districts. The potassium soluble in strong hydrochloric acid is largely present in forms other than the zeolite. While the zeolite potassium in the subsoil is in all cases less than the surface soil, like the sodium, it is not markedly less when compared with the divalent bases calcium and magnesium. In fact, it is very significant that a great difference exists in the divalent zeolite bases present in the soil and subsoil, while a close agreement exists in the monovalent bases present in the soil and subsoil. There is some variation in the zeolite potassium in Kilauea soils, but this is in no way related to the good, fair and poor classifications, and, on the whole, the Kilauea soils contain just as much zeolite potassium as the fertile soils from other districts. The soils from both the good Fields 7 and 21, are highest in citric soluble potassium, but otherwise they do not differ from the soils in other fields, especially in the amount of potassium present as zeolite. This low solubility of zeolite potassium in Kilauea soils is very significant and indicates that the solubility in 1 per cent citric acid is, for Hawaiian soils, a better indication of availability than the replaceable potassium determination.

Replacement capacity: The amount of base which a soil is capable of fixing is usually referred to as its replacement capacity. This property is being extensively determined in studying soil properties. As applied to the soils, which we have used in this study, the replacement capacity is not significant and, other than the lower capacity of the subsoils as compared to surface soils, it is of little interest to our problem.

The soils 2827-31 and 2835-6, shown at the bottom of Table I, were taken from three potash experiments at Kilauea, and they represent check plots and potash plots from each experiment. All are from fields which are classified as poor, and the samples were taken in order to determine in what form the potash

had been fixed under field conditions. In Field 28, samples 2728-31, there was no response to heavy applications of potash. In Field 25, samples 2835-6, there was a small but consistent response. The data show that the zeolite potassium has been notably increased by the heavy fertilization, especially in 2827, where 1,500 pounds K_2O per acre was added with no response, and that it has been fixed as the zeolite which should be available to the plant. It appears, though, that like the zeolite potassium already present in the soil, it has been fixed in a form insoluble or difficultly soluble in 1 per cent citric acid. Furthermore, if the crop performance is any criterion, the fixation is beyond the limits of availability. In all three cases the hydrochloric acid soluble potassium is greater in the potash plots than the checks. While one cannot base conclusions on so few data, knowing the fluctuation in hydrochloric acid soluble potassium in soils and the difficulty in measuring small differences with this solvent, nevertheless the higher hydrochloric acid soluble potassium is significant and may indicate some fixation in a form even less available than the zeolite.

It is very evident from the preceding data and discussion that there is a great difference between the fixing power of the Kilauea soils and those from the more fertile districts, which are deficient and give response to potash fertilization or have been shown to be well supplied with available potassium. This applied only to the fixation of the monovalent bases potassium and sodium and not to the divalent bases calcium and magnesium. Aarnio(1) has recently noted a similar condition in the peat soils of Finland and says: "If peat is saturated with calcium and potassium ions, the potassium ions reduce the acidity more than the calcium ions. The absorbed potassium ions are attached *more firmly* than the calcium ions and their influence must therefore be *more 'tenacious'* than that of the calcium ions." He interprets from his observations that it would be advantageous to add large amounts of potash with lime in correcting the acidity of peat soils. The zeolites with fixing and replacing properties are largely present in the finer soil particles, the colloidal clay fraction. May it not be true then that we have in the Kilauea clay a different type of zeolite? The first thing that strikes one on examining the Kilauea fields is the peculiar appearance of the clay or colloidal state. On drying, there is often the appearance of the shotty texture characteristic of many of the Hamakua soils on Hawaii. On wetting, although the clay fraction appears small, the clay will become highly dispersed and will clog up the pores of the soil. This is particularly true of the yellow clay soils, most of the better fields being of the red clay types. It is characteristic of the clay fraction of these yellow types from the poor fields to remain in suspension indefinitely when shaken with water in a glass cylinder, which is in direct contrast to the clay from the good fields which settles fairly readily under the same treatment.

It is generally recognized, and in fact it has been fairly well established, that the zeolites have a greater affinity for the divalent bases calcium and magnesium than for the monovalent bases sodium and potassium and, therefore, that they should be more strongly fixed. As measured by solution in 1 per cent citric acid, this holds true for the Ewa, Waipio and Hilo soils, but it is not true of the Kilauea soils. This also indicates a difference in the character and property of the Kilauea soil zeolite, which is probably associated with the poor availability of potassium

The fact that some soils have the property of fixing potassium in a form less available than the zeolite potassium has been observed by others. Quoting Truog(5), Wisconsin Experiment Station: "There appears to be some evidence that potassium, at least in part, goes over to a more insoluble form subsequent to its fixation as a replacement base in the colloidal complex. As a result of this the potassium becomes less available, and it would seem that the more desirable field practice would be to apply potash fertilizers in small, frequent applications rather than the reverse." A similar view is held by MacIntire(3) of the Tennessee Experiment Station, who says: "Some of our findings at Tennessee seem to substantiate the conclusion that whereas a part of the added potassium becomes leached a greater part becomes fixed by the soil. Some of the fixed potassium may be considered as fixed in a form which will yield fairly well to the pull exerted by the plant, whereas some of it may be considered as being rendered relatively insoluble. Using the observed parallel relative to the progressive decrease in solubility of calcium and magnesium which had been fixed from caustic and carbonate additions, it may be assumed that fixed potassium will continue to pass into forms more complex and less soluble."

As shown by the work of Breazeale(2), and this has been confirmed by other investigators, zeolite potassium should be just as available when subject to the feeding activities of plant roots as the soluble salts of potassium, such as the chloride or sulphate. On this basis we plan to study the availability of potassium, using the plant as the final indicator.

The availability of zeolite potassium is brought about through a hydrolysis and ionization of the zeolite complex by which process the potassium ion is brought into solution. As a means of studying this phenomenon in soils the dialysis of the soil zeolites has recently been extensively studied. By such a treatment the soil may be placed in a semipermeable bag of parchment or collodion placed in a vessel of distilled water and by intermittently removing the water from the vessel and replacing with fresh water the products of ionization and hydrolysis may be removed and quantitatively determined. The speed of dialysis may be greatly increased by applying an electric current to electrodes placed outside the dialysing membrane containing the colloid, a process known as electrodialysis. In order to see if electrodialysis would lend any information regarding the peculiar fixing property of Kilauea soils, a rather extensive study of this has been made, and is made the subject of an accompanying paper.

SUMMARY

The relation between the bases soluble in 1 per cent citric acid, strong hydrochloric acid and that present in the form of zeolite has been determined in a representative set of soils from Kilauea plantation and compared with several other soil types of known potash availability.

The availability of potash in Kilauea soils, as measured by 1 per cent citric acid is very low.

Zeolite potassium in Kilauea soils compares very well with other island soils, but the solubility of zeolite potassium in citric acid is much lower in the former.

Potassium added in fertilizer is fixed by the soil zeolites in the Kilauea soils, just as in the Waipio soil, and appears to be just as reactive to replacement, but for some unknown reason the plant does not respond as it should.

There does not appear to be any relation between the amount and forms of other bases and the availability of potassium in this series of soils.

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TABLE I
SHOWING PER CENT BASES AND HYDROGEN IN SOILS, ON DRY BASIS

| Soil No. | Cane Growth | Calcium (Ca) | | | Potassium (K) | | | Magnesium (Mg) | | | Sodium (Na) | | | Hydrogen as Zeolite (H) |
|---------------------|-------------|--------------|----------------|---------|---------------|----------------|---------|----------------|----------------|---------|-------------|----------------|---------|-------------------------|
| | | HCL Soluble | Citric Soluble | Zeolite | HCL Soluble | Citric Soluble | Zeolite | HCL Soluble | Citric Soluble | Zeolite | HCL Soluble | Citric Soluble | Zeolite | |
| 2a | Fair | .35 | .228 | .280 | .41 | .014 | .024 | .23 | .024 | .017 | .36 | .017 | .038 | .004 |
| 2b | | .25 | .091 | .122 | .36 | .013 | .021 | .31 | .014 | .004 | .29 | .018 | .028 | .008 |
| 5a | Fair | .23 | .093 | .105 | .19 | .013 | .020 | .24 | .052 | .030 | .19 | .015 | .032 | .006 |
| 5b | | .23 | .037 | .038 | .26 | .013 | .021 | .18 | .015 | .012 | .23 | .014 | .024 | .0038 |
| 7a | Good | .32 | .144 | .198 | .36 | .019 | .030 | .34 | .094 | .070 | .28 | .020 | .058 | .0073 |
| 7b | | .17 | .059 | .070 | .30 | .008 | .034 | .27 | .022 | .018 | .26 | .018 | .036 | .0033 |
| 11a | Fair | .26 | .107 | .144 | .20 | .015 | .023 | .29 | .031 | .017 | .29 | .017 | .023 | .0082 |
| 11b | | .22 | .049 | .050 | .25 | .013 | .019 | .23 | .014 | .009 | .39 | .019 | .037 | .0048 |
| 12 ^{1/2} a | Poor | .20 | .070 | .101 | .30 | .017 | .030 | .15 | .034 | .015 | .27 | .019 | .029 | .0098 |
| 12 ^{1/2} b | | .15 | .039 | .040 | .29 | .013 | .022 | .14 | .015 | .007 | .27 | .015 | .023 | .005 |
| *14a | Poor | 1.61 | 1.22 | .400 | .17 | .017 | .030 | .29 | .085 | .013 | .25 | .021 | .030 | ..... |
| 14b | | .49 | .282 | .213 | .04 | .... | .015 | .14 | .022 | .008 | .23 | .... | .024 | .0013 |
| 16a | Fair | .20 | .089 | .104 | .37 | .014 | .021 | .13 | .045 | .034 | .21 | .023 | .052 | .0102 |
| 16b | | .15 | .035 | .040 | .35 | .013 | .016 | .30 | .022 | .007 | .17 | .022 | .030 | .0046 |
| 21a | Good | .33 | .149 | .213 | .29 | .022 | .038 | .28 | .045 | .040 | .20 | .018 | .035 | .0049 |
| 21b | | .19 | .078 | .092 | .34 | .018 | .019 | .24 | .030 | .011 | .23 | .024 | .042 | .001 |
| 24a | Poor | .50 | .345 | .450 | .32 | .009 | .015 | .31 | .037 | .002 | .16 | .016 | .032 | .0024 |
| 24b | | .13 | .048 | .053 | .30 | .005 | .... | .41 | .008 | .002 | .20 | .012 | .... | .0075 |
| *28a | Poor | .53 | .344 | .364 | .33 | .006 | .025 | .12 | .026 | .029 | .24 | .014 | .027 | ..... |
| 28b | | .19 | .051 | .055 | .33 | .... | .019 | .12 | .005 | .003 | .26 | .019 | .033 | .008 |
| 33a | Poor | .44 | .183 | .240 | .25 | .007 | .043 | .32 | .049 | .087 | .23 | .018 | .044 | .0078 |
| 33b | | .14 | .039 | .... | .20 | .018 | .022 | .13 | .015 | .013 | .22 | .011 | .039 | .0106 |
| *37a | Poor | 1.75 | 1.140 | .447 | .25 | .015 | .032 | .35 | .083 | .021 | .25 | .016 | .034 | ..... |
| 37b | | .32 | .215 | .047 | .16 | .014 | .019 | .07 | .015 | .016 | .29 | .016 | .043 | .0047 |
| H | | .22 | .026 | .184 | .16 | .009 | .011 | .34 | .002 | .015 | .37 | .017 | .036 | .018 |
| V | | .32 | .117 | .209 | .20 | .035 | .027 | .24 | .049 | .067 | .35 | .036 | .034 | ..... |
| VK | | .35 | .153 | .... | .19 | .040 | .049 | .26 | .065 | .084 | .33 | .034 | .040 | ..... |
| 19B | | .39 | .166 | .208 | .13 | .014 | .011 | .35 | .090 | .124 | .38 | .064 | .037 | ..... |
| | | .50 | .212 | .364 | .23 | .033 | .051 | .64 | .126 | .169 | .38 | .052 | .049 | ..... |
| *2827 | Poor | 2.02 | 1.27 | .528 | .28 | .007 | .050 | .... | .... | .114 | .... | .... | .025 | ..... |
| 2828 | Poor | .23 | .19 | .319 | .17 | .008 | .012 | .... | .... | .021 | .... | .... | .029 | .0048 |
| 2829 | Poor | .28 | .26 | .378 | .15 | .013 | .012 | .... | .... | .020 | .... | .... | .024 | ..... |
| *2830 | Poor | .42 | .39 | .542 | .16 | .011 | .012 | .... | .... | .025 | .... | .... | .022 | ..... |
| *2831 | Poor | 1.38 | .92 | .760 | .21 | .017 | .021 | .... | .... | .037 | .... | .... | .028 | ..... |
| 2835 | Poor | .10 | .05 | .117 | .28 | .013 | .012 | .... | .... | .009 | .... | .... | .021 | .0088 |
| 2836 | Poor | .10 | .06 | .121 | .34 | .015 | .021 | .... | .... | .015 | .... | .... | .017 | .0080 |

* Coral sand in soils.

TABLE II
Showing Zeolite Bases Calculated as Milligram Equivalents per 100 Gms. Soil

| Soil No. | Calcium | | Magnesium | | Potassium | | Sodium | | Hydrogen | | Total Replacement Capacity by Ammonium Acetate | |
|----------|---------|---------|-----------|---------|-----------|---------|--------|---------|----------|---------|--|---------|
| | Soil | Subsoil | Soil | Subsoil | Soil | Subsoil | Soil | Subsoil | Soil | Subsoil | Soil | Subsoil |
| 2 | 13.9 | 6.0 | 1.3 | .3 | .6 | .5 | 1.6 | 1.2 | 4.0 | 8.2 | 17.2 | 14.3 |
| 5 | 5.2 | 1.9 | 2.0 | 1.2 | .5 | .5 | 1.3 | 1.0 | 6.0 | 3.8 | 14.0 | 7.1 |
| 7 | 9.8 | 3.4 | 5.7 | 1.4 | .7 | .8 | 2.5 | 1.5 | 7.3 | 3.3 | 21.3 | 9.2 |
| 11 | 7.1 | 2.4 | 1.4 | .7 | .5 | .5 | 1.0 | 1.6 | 8.2 | 4.8 | 17.2 | 10.3 |
| 12½ | 5.0 | 1.9 | 1.2 | .6 | .7 | .5 | 1.2 | 1.0 | 9.8 | 5.0 | 16.4 | 9.8 |
| 14* | 19.0 | 10.6 | 1.0 | .6 | .7 | .4 | 1.3 | 1.0 | 0.0 | 1.3 | 16.7 | 13.2 |
| 16 | 5.1 | 1.9 | 2.7 | .6 | .5 | .4 | 2.2 | 1.3 | 10.2 | 4.6 | 18.1 | 11.2 |
| 21 | 10.6 | 4.5 | 3.2 | .9 | .9 | .5 | 1.5 | 1.8 | 4.9 | 1.0 | 20.2 | 10.0 |
| 24 | 22.4 | 2.6 | .1 | .1 | .4 | .. | 1.3 | ... | 2.4 | 7.5 | 21.1 | 11.2 |
| 28* | 18.1 | 2.7 | 2.3 | .2 | .6 | .5 | 1.1 | 1.4 | 0.0 | 8.0 | 16.9 | 13.6 |
| 33 | 11.9 | ... | 7.1 | 1.0 | 1.1 | .5 | 1.9 | 1.6 | 7.8 | 10.6 | 27.2 | 16.0 |
| 37* | 22.3 | 2.3 | 1.7 | 1.3 | .8 | .5 | 1.4 | 1.8 | 0.0 | 4.7 | 18.4 | 11.7 |
| H | 9.1 | ... | 1.2 | ... | .3 | .. | 1.5 | ... | 18.7 | ... | 29.5 | ... |
| V | 10.4 | ... | 5.1 | ... | .3 | .. | 1.4 | ... | ... | ... | 16.8 | ... |
| VK | .... | ... | 6.9 | ... | .9 | .. | 1.7 | ... | ... | ... | 18.4 | ... |
| 11 | 10.3 | ... | 10.1 | ... | .3 | .. | 1.6 | ... | ... | ... | .... | .... |
| 19B | 18.1 | ... | 13.8 | ... | 1.3 | .. | 2.1 | ... | ... | ... | 31.6 | .. |

* Coral sand in soils.

Soil Acidity: Replaceable Hydrogen and Replacement Capacity

By W. T. McGEORGE

The use of lime in the fertilizer programme on the acid soils of our island plantations has been for a number of years a question for controversy. There is a feeling that lime should help to maintain a more permanent soil fertility and, on this basis, if no other, its use to some appears to be warranted. There are on record cases of injury from lime; others where no effect one way or another was noted; others in which response was obtained in the first crop following its application, and still others where no effect was noted until the third or even fourth crop after liming.

It is characteristic of our plantation areas that, proceeding mauka from lower elevations, there is a corresponding increase in the acidity of the soil. Likewise there is a corresponding decrease in sugar yields. One exception to the variation in soil reaction is of interest and significance. In the Kau district on the island of Hawaii, where cane is grown up to an altitude of 3,000 feet, the soils are practically neutral. That is, they do not show the acidity characteristic of mauka soils. Acid mauka soils are characterized by low availability of plant food and sluggish biological life, both of which are stimulated by neutralization of soil acidity.

During the past two years we have devoted considerable time to an investigation of the factors associated with the low fertility of the soils of Kilauea plantation. From a close observation of the poorer soil types located on this plantation, few there are who would fail to suggest lime as one soil amendment in any programme of fertilization. The soils contain a highly colloidal form of clay, which is in a high state of dispersion, and they are, in the main, acid soils. So it is not surprising that during the last twenty years coral sand has been applied many times to Kilauea fields, but with variable results. Often the spots in the fields where the lime had been piled preparatory to broadcasting—such spots would be heavily limed—gave notable response. But in other fields serious injury to cane growth on such spots was noted. Similar variation has been noted in field experiments, and no materially profitable return has been obtained. The fact that in some cases response has been noted, coupled with our knowledge of the general character of Kilauea soils, has led us to still feel that an improvement in fertility should involve applications of lime in some form. The records on file covering lime experiments at Kilauea show that out of seventeen observations nine gave some response, either in the spots where the lime was piled for broadcasting or in the broadcasted areas, while eight gave none or injured the cane growth. The amounts applied varied from half a ton per acre to as high as thirty-six tons per acre, and no relation between soil reaction or soil type and response was evident.

The same is more or less true of lime experiments conducted in other parts of the islands by the Experiment Station, in that harvesting results have not per-

mitted definite interpretations regarding the effect of lime. There has been evidence of response to lime on neutral soils. On acid soils there has been little to lend encouragement to the advocates of liming(6). The question therefore arises, have we sufficient understanding of the nature of our soil acids, and have we properly satisfied the lime requirement of our soils, or have we overlooked other essential, associated, growth-limiting factors which may be present in our acid types?

It is well known and widely recognized that many plants prefer and grow best at rather closely defined ranges of soil reaction, and that for most plants, where little preference is shown, a reaction of approximately pH 6.5 is most suitable. We have no direct evidence of soil reaction preference in sugar cane, but the comparative growth of cane in the neutral mauka fields of Kau and the acid mauka fields of Hamakua suggests a reaction near neutrality. However, for the present let us drop the more specific reaction preference of the cane plant, which would be greatly complicated by the number of cane varieties which we grow, as well as the difference in lime requirement of the plant, and take up the lime requirement of the soil, that is, the amount of lime required to bring the soil to neutrality or some other definite reaction. Except for a few acid-loving-calcifuge-plants, most crops are not at their best in an acid soil environment and hence for centuries it has been the practice to "sweeten" acid soils with lime, one of our oldest fertilizer materials.

Methods for the determination of the lime requirement of the soil are legion, but few, if any, have been extensively adopted in spite of the fact that in specific cases some one method has been used to advantage. We have, therefore, attempted in connection with our Kilauea soil investigations, to first seek some fundamental information regarding acidity in our island soils. There are, at Kilauea, soils on which lime has shown both response and injury, so that conditions there present an excellent opportunity for gaining some rather definite information on the liming problem.

SOIL ACIDITY

Soil acidity has been variously attributed to physical adsorption, chemical absorption, free hydrogen ions, presence of silicic acid, hydrolysible salts of iron and aluminum, organic acids, and the complex silicates known as zeolites, which are components of the colloidal clay fraction of the soil sometimes referred to as the alumino-silicate complex.

The first conception of soil acidity involved the presence of the so-called humus acids, formed from the decomposition of plant remains. Later, the absorptive property of the soil was recognized, to which was attributed the change in color of litmus paper when used for testing the soil reaction. As our knowledge of soil acidity broadened, evidence of several types of acidity appeared and we had:

1. True, active, or free acidity from such acids as nitric, sulphuric or hydrochloric, sometimes referred to as soluble acidity.
2. Interchange or exchange acidity released from the soil by salts of strong acids and believed by some to be due to the interchange of basic ions for iron

and aluminum, the salts of which, when in solution, will hydrolyze with an acid reaction.

3. Hydrolytic acidity developed in the hydrolytic splitting off of salts of weak acids.

The situation was later further complicated by the use of such terms as actual acidity and potential acidity. The former term applied to the free hydrogen ion concentration, or pH, and the latter to the amount of base required to completely saturate the soil.

It is now gratifying to note that the above more or less confusing array of terms and forms of acidity has been greatly clarified by the latest advances in soil research and, too, greatly simplified. In other words, it is now definitely established that soils contain alumino-silicate complexes, components of the colloidal clay fraction of the soil, which are the seat of absorption or ionic exchange phenomena and are, in large part, involved in all changes in soil reaction. In fact, some of the leaders in soil research go so far as to now maintain that all soil acidity is essentially as above and of one kind(5).

There may be present in this absorptive component of clay, bases such as calcium, magnesium, sodium and potassium, or the hydrogen ion, all of which are subject to exchange with other soluble bases or hydrogen of a solution with which the clay may be brought in contact. All soils have a rather definitely defined capacity for absorption, usually referred to as the saturation capacity. In most part calcium is the predominant base, and such soils are usually the fertile types. Any deviation from this condition often works to seriously injure the soil properties, black alkali soils being types in which the complex is in large part combined with sodium. If the saturation capacity is in certain part combined with hydrogen, soil acidity is manifested. There is a notable variation in the affinity which the absorbing complex—the clay—shows toward different bases and hydrogen, and it is greater for hydrogen than for any of the bases. Therefore, even such weak acids as carbonic acid, present in rain water, and the organic acids formed in the decomposition of plant residues, are extremely active in the replacement of bases in the soil. These are the conditions found in our mauka fields and have been largely involved in the development of acidity in these areas. Added to this, there has been a notable depletion of soil bases, such as calcium which, too, makes for greater absorption of hydrogen.

EXPERIMENTAL

In the correction of soil acidity, or the liming of soils, it becomes of fundamental importance to have some knowledge of the saturation capacity of the soil and to know in what part this capacity is satisfied by bases and with hydrogen. The exchange property of the absorbed bases of the clay is such as to be greatly and easily modified by contact with solutions of salts or acids. Thus it is possible to remove all other absorbed bases or hydrogen by leaching the soil with a definite soluble basic salt and, by analyzing the leachate, to determine the nature of the absorbed ions. This method has therefore been universally adopted for determining the absorbed or replaceable bases and hydrogen in soils.

On account of the difference in affinity of the absorbing complex for bases and hydrogen, some salts are more active as replacing agents than others. This is especially true of the replacement of hydrogen and there is a notable difference, also, in the rate of hydrogen replacement by the salts of strong acids, such as calcium chloride, and the salts of weak acids, such as calcium acetate.

For a study of some of these factors and of the properties of our acid island soils, four widely varying and representative types were selected.

1. Red clay soil, pH 4.8 characteristic of the acid clay soils of the islands and which types are found in lowest pH or of highest acidity.

2. Yellowish brown silt loam from Honokaa plantation pH 5.5. This acid soil is well supplied with organic matter, but less than soil number 3 and from a less humid district.

3. Black highly organic silt from Olaa plantation pH 5.7. This is a soil of comparatively recent formation, very high in organic matter, and from one of our most humid districts.

4. Heavy black acid clay type pH 5.8. This soil, as an additional deviation from normal, also contains unusually large amount of replaceable magnesium.

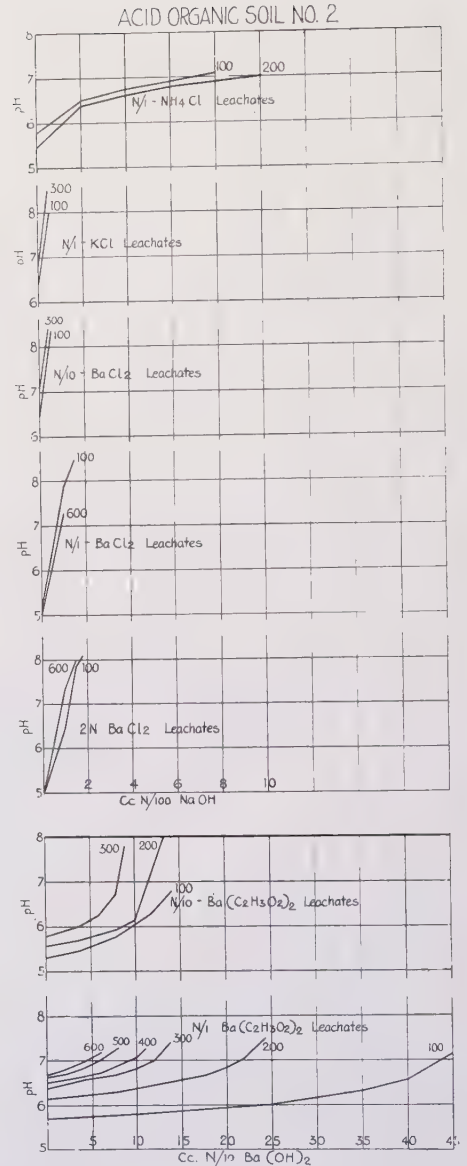
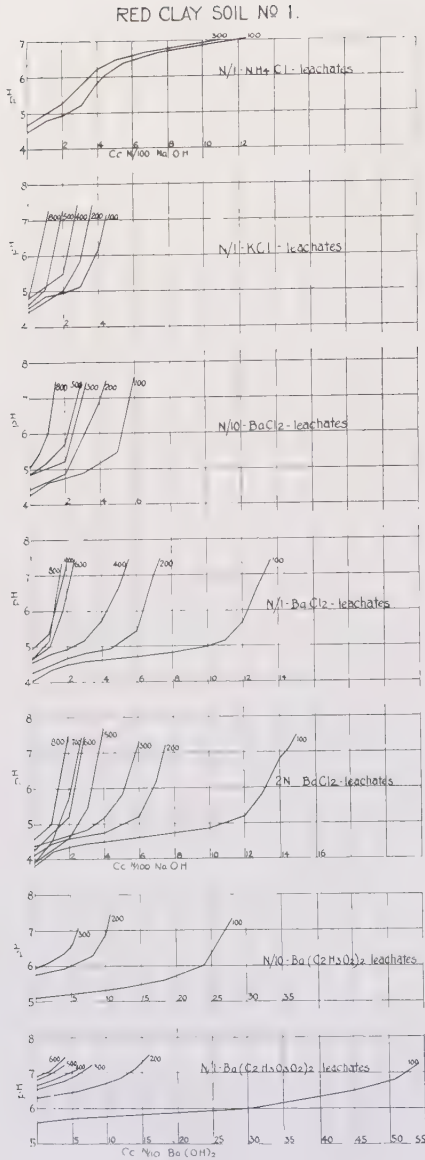
Four salt solutions of the following concentration were used for the replacement of the hydrogen. Normal ammonium chloride; normal potassium chloride; twice normal, normal and tenth-normal barium chloride; and normal and tenth-normal barium acetate.

Twenty-five grams of air-dried soils were weighed into glass cylinders, one inch diameter, especially adapted for leaching soils with salt solutions. The soil columns were leached with successive 100 c.c. portions of the salt solutions, and each 100 c.c. leachate titrated with standard alkali, using the quinhydrone electrode. Readings were taken with the electrode at successive additions of alkali, and the data are presented graphically in Figs. 1, 2, 3, 4, in lieu of presenting the large amount of tabulated data.

Each titration curve is designated as 100, 500, etc., representing the titration of the first 100 c.c., fifth 100 c.c., etc., of leachate. In cases where there was little or no variation in the titration of successive leachings, such as was the case with the chlorides, some of the curves are omitted for the clarity of the graph. These graphs show the reaction of the displaced solution, the rate of hydrogen replacement, and the total amount of hydrogen displaced is shown by the volume of standard alkali required to bring the displaced solutions to neutrality.

The purpose of the experiment was not quantitative, but rather to obtain information regarding the comparative replacing power of the salts of strong acids and the salts of weak acids, and to learn something of the comparative properties of our acid clay soils and acid organic soils.

It is quite evident that our island acid soils are potentially highly unsaturated, that is, unsaturated with respect to bases. The organic soils show only very small amounts of so-called exchange acidity, that is, acidity replaced by the salts of the strong acids, while considerably more hydrogen is displaced from the acid clay by these salts. These data indicate that it would be impossible to replace the hydrogen with a chloride within any reasonable time limit. However, when leached with barium acetate, the salt of both a weak acid and weak base, the replacement was



apparently complete. This shows that the acidity of our island soils is largely the so-called hydrolytic acidity. The ratio of amount of hydrogen replaced in the first 100 c.c. of normal barium chloride to that replaced by the first 100 c.c. of barium acetate is of interest, and is as follows:

| | |
|------------|-------|
| Soil No. 1 | 1:41 |
| Soil No. 2 | 1:630 |
| Soil No. 3 | 1:265 |
| Soil No. 4 | 1:300 |

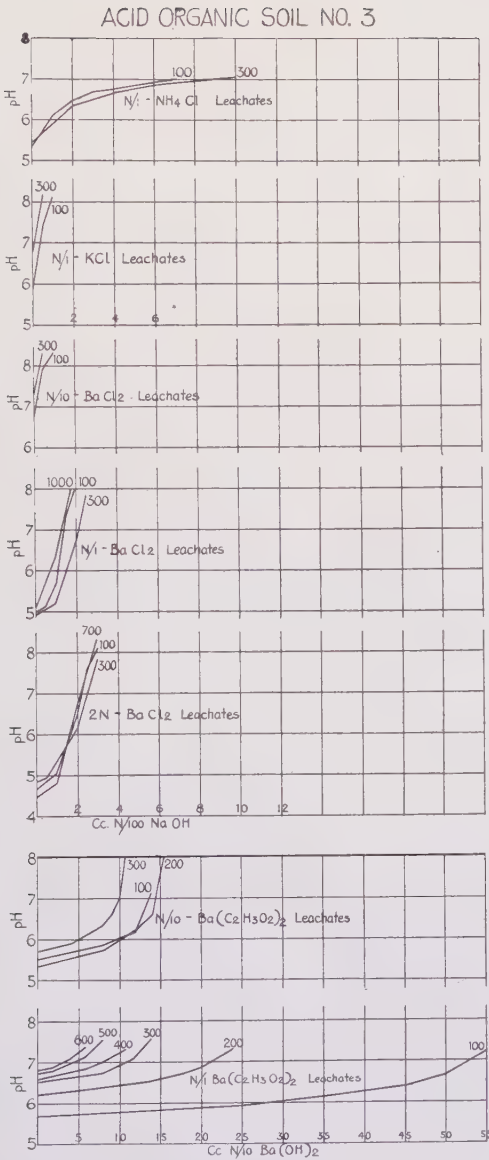


Fig. 3

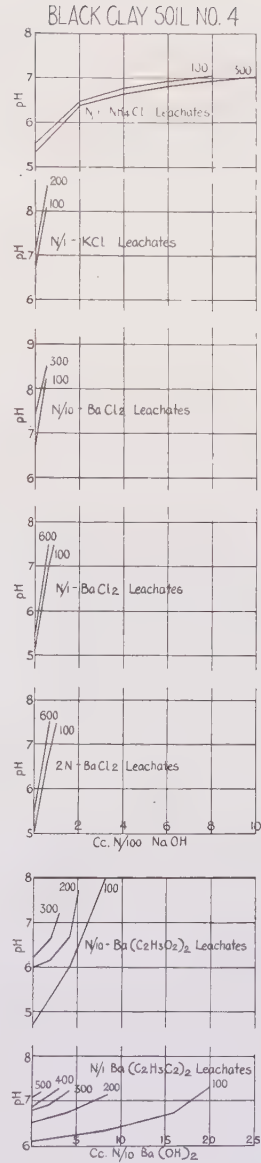


Fig. 4

On the basis of the above we should expect a more active acidity in the acid clays and a higher equilibrium concentration for soil hydrogen.

QUANTITATIVE

It is evident from the preceding experiments that any quantitative determination of the degree of unsaturation, or the replaceable hydrogen content of our Island soils, should involve the use of a basic acetate. Barium being the most active replacing base, the acetate of this salt is to be preferred, also, that a normal solution be used and as small a sample of soil as possible be employed. From the

amount of N/10 alkali used in the titration of the leachates from 25 grams of soil, it is evident that 5 grams of soil is ample.

Some investigators have recommended normal barium chloride for the quantitative determination of replaceable hydrogen, leaching the soil until the leachate no longer shows acidity, and among these are Gedroiz(2) and Joffe and McLean(4). Such a method appears to be entirely unsuited to local soils and is an endless procedure, if even possible at all, which is to be doubted. The replacement of hydrogen or its exchange properties are materially affected by the hydrogen ion concentration of the leaching solution. Salts of strong acids, such as the chlorides, which are highly ionized and poorly buffered, will therefore have very weak replacement properties for hydrogen in acid soils. This is because sufficient hydrogen ions will be present to prevent the replacement reaction going to completion. Barium acetate is the salt of a weak acid. Solutions of this salt have a very low ionization value, and are highly buffered. Therefore the replacement reaction between barium acetate and fixed hydrogen will proceed rapidly toward completion.

Through communication with W. P. Kelley, Citrus Experiment Station, Riverside, California, and F. W. Parker, Alabama Experiment Station, we learned of their investigations on this same problem and they kindly submitted quantitative methods which they had developed. In one case Parker determines the exchange capacity of the soil, the exchange base content, and then calculates the replaceable hydrogen by difference. In another he leaches the soil with a neutral solution of barium acetate and titrates the leachate in the same manner used by us in our preliminary work, thus determining the replaceable hydrogen direct:

Exchange capacity of soil: Five grams of soil are treated at room temperature with 100 c.c. of N/10 $\text{Ba}(\text{OH})_2$, for a period of 16 to 18 hours. The whole is then filtered by suction through a Gooch crucible, the soil too being transferred. The soil in the crucible is then leached with 250 c.c. of N/1 NH_4Cl , then carefully washed with ethyl alcohol until free from chlorides. The NH_4 fixed by the soil is then determined which represents the total replacement capacity of the soil.

Exchangeable base content: Five grams of soil are placed in a Gooch crucible and leached with 250 c.c. of N/1 BaCl_2 . The leachings are titrated with N/10 $\text{Ba}(\text{OH})_2$ to determine the amount of hydrogen replaced by the barium. The soil is then leached with N/1 NH_4Cl until the leachings no longer give a test for barium and the barium determined as BaSO_4 . Expressed in chemical equivalents, the amount of barium absorbed minus the hydrogen replaced gives the replaceable base content of the soil.

Barium acetate method: Five grams of soil are placed in a Gooch crucible and leached with 250 c.c. of N/1 $\text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2$ and the leachings titrated electrometrically to pH 7.0. It is essential that the reaction of the barium acetate used for leaching the soil be exactly neutral.

It is of interest to mention that Parker found a complete replacement of hydrogen by his barium acetate method.

Using the same four soils as employed in our preliminary experiments, determinations being made in duplicate, the following results expressed in milliequivalent terms were obtained*:

* We have adopted the plan, throughout this paper, of expressing results on a milliequivalent basis (M.E., milligram equivalents per 100 grams soil), so that any base is directly comparable with another or with hydrogen in the proportion by weight at which they are capable of replacing each other or of combining with other ions to form salts.

TABLE I

Showing Replacement Capacity and Replaceable Hydrogen by Parker Method

| Soil Number | 1 | 2 | 3 | 4 |
|--|-------|-------|-------|-------|
| Total exchange capacity..... | 25.0 | 51.9 | 48.3 | 63.5 |
| Barium fixed by soil..... | 8.36 | 14.94 | 17.55 | 53.33 |
| Hydrogen in BaCl ₂ sol..... | 4.8 | 1.1 | 3.0 | 1.0 |
| Total bases by difference..... | 3.56 | 13.84 | 14.55 | 52.33 |
| Replaceable hydrogen by difference..... | 21.44 | 38.06 | 33.75 | 11.17 |
| Replaceable hydrogen by titration Ba(C ₂ H ₃ O ₂) ₂ | 20.99 | 27.77 | 24.80 | 8.92 |

In the method submitted by Kelley the soil is treated with N/10 Ba(OH)₂, as in Parker's method, and leached with a neutral solution of N/1 ammonium acetate as long as the leachate shows a test for bases. The soil is then leached with a neutral solution of methyl* alcohol until the leachate is free from NH₄, and the total ammonium absorbed determined, which represents the total replacement capacity. The difference between this and replaceable bases in the soil represents replaceable hydrogen. The results obtained by this method are given below as milliequivalents:

TABLE II

Showing Replacement Capacity by Two Methods

| Soil Number | 1 | 2 | 3 | 4 |
|---|------|------|------|------|
| Total replacement capacity—Kelley | 25.4 | 51.7 | 48.3 | 63.6 |
| Total replacement capacity—Parker | 25.0 | 51.9 | 48.3 | 63.5 |

All the salt solutions used in the above were carefully neutralized to pH 7.0 before the leaching. Determinations were all made in duplicate and good checks were obtained. The two methods give very closely agreeing results considering the high saturation capacity of the soils used. On the other hand, there is a serious discrepancy in the replaceable hydrogen as determined by titration and by the difference method of Parker. Kelley does not specify in what manner the total replaceable base content shall be determined, but, if we use the method suggested by Parker, the following results as milliequivalents are obtained:

TABLE III

Showing Replaceable Hydrogen by Difference and by Titration

| Soil Number | 1 | 2 | 3 | 4 |
|---|------|------|------|------|
| Total replacement capacity—Kelley..... | 25.4 | 51.7 | 48.3 | 63.6 |
| Total bases—Parker | 3.5 | 13.8 | 14.5 | 52.3 |
| Replaceable hydrogen by difference..... | 21.9 | 37.9 | 33.8 | 11.3 |
| Replaceable hydrogen by titration..... | 20.9 | 27.7 | 24.8 | 8.9 |

For example, if a soil contains 0.400 per cent calcium we would express this on a milliequivalent basis as follows:

$$\frac{\text{milligrams per 100 grams soil} - 400}{\text{atomic weight} - 40.07} \times \text{valency} - 2 = \text{M. E.} - 19.96.$$

* Methyl alcohol is a non-hydrolyzing and coagulating solvent.

Here it is noted that in soils 1 and 4 there is close agreement, but wide discrepancies in soils 2 and 3.

In order to confirm this apparent error, the replaceable bases sodium, potassium, calcium and magnesium were carefully determined by displacement with normal solutions of ammonium chloride and ammonium acetate and tenth normal solutions of barium chloride and barium acetate. All these salt solutions gave closely agreeing results and those obtained with ammonium acetate are given in the following table:

TABLE IV

M. E. Replaceable Bases

| Soil No. | Sodium | Potassium | Calcium | Magnesium | Total |
|----------|--------|-----------|---------|-----------|-------|
| 1 | .90 | .6 | 2.0 | 1.1 | 4.6 |
| 2 | 1.31 | .7 | 8.0 | 2.5 | 12.5 |
| 3 | 1.44 | .7 | 10.6 | 2.9 | 15.6 |
| 4 | 5.4 | 1.2 | 12.7 | 35.3 | 54.6 |

In Table V the sum of the bases calcium, magnesium, sodium and potassium, in milliequivalents, is added to the hydrogen as determined by titration.

TABLE V

Showing Replacement Capacity by Three Methods

| Soil Number | 1 | 2 | 3 | 4 |
|---|-------|-------|------|------|
| Total bases, separately determined..... | 4.6 | 12.5 | 15.6 | 54.6 |
| Hydrogen by titration..... | 20.99 | 27.77 | 24.8 | 8.92 |
| Total replacement capacity..... | 25.59 | 40.27 | 40.4 | 63.5 |
| Total replacement—Parker Method..... | 25.0 | 51.9 | 48.2 | 63.5 |
| Total replacement—Kelley Method..... | 25.4 | 51.7 | 48.3 | 63.6 |

Only in two soils, 1 and 4, does the sum of the bases and hydrogen agree with the total replacement capacity as determined by preliminary neutralization of the soil acidity with barium hydroxide.

Following the above we next took a slightly alkaline soil, a red clay type from Ewa plantation, Oahu, reaction pH 7.8, and followed the same analytical procedure as above, with the following results:

TABLE VI

Showing Replaceable Bases and Replacement Capacity of Neutral Clay Soil

| | |
|--|------|
| Replaceable calcium | 6.0 |
| Replaceable magnesium | 6.8 |
| Replaceable sodium | 1.3 |
| Replaceable potassium | 0.4 |
| Replaceable hydrogen—barium acetate..... | 0.0 |
| Total replaceable bases..... | 14.5 |
| Replacement capacity—Parker | 13.9 |
| Replacement capacity—Kelley | 13.9 |

While the total replacement capacity of this soil is less than the acid soils, the agreement between the three methods is nevertheless quite close. On leaching this soil with neutral barium acetate the leachate had the same reaction using the quinhydrone electrode, as the original solution, showing no replaceable hydrogen.

There is much evidence in the preceding data that a preliminary treatment of the soil with barium hydroxide will, in some acid soils, show a fixation of base in excess of the saturation capacity of the soil. It is significant that soils 2 and 3, which show this property, are highly organic types. Organic matter may therefore be associated with "excess" base absorption. Among other possible associated factors may be included, replaceable iron and aluminum, hydroxyl ion fixation, fixation as basic salts or aluminates, and the conversion of barium hydrate into barium carbonate by the carbon dioxide in the air.

The comparative organic matter present in these soils was determined as total carbon, and the results are given in the following table:

TABLE VII
Showing Per Cent Carbon in Soils

| Soil No. | Total Carbon Per Cent |
|----------|-----------------------|
| 1 | 4.99 |
| 2 | 9.69 |
| 3 | 13.60 |
| 4 | 3.00 |
| 5 | 1.22 |

These data show an apparent relation between "excess" fixation of base and give further evidence that the soil organic matter is in some way involved.

The higher saturation capacity obtained where the soils receive a preliminary treatment with barium hydroxide strongly indicates that there is, at least in part, an hydroxyl absorption by the soil. This is further shown by the following experiment: Five-gram portions of the five soils were weighed in duplicate; one sample was placed directly in Gooch crucibles and leached with 250 c.c. of normal barium acetate, then washed with neutral methyl alcohol until free of soluble barium, and finally leached with 250 c.c. of neutral ammonium acetate. The barium was determined in the leachate, and the ammonium fixed by the soil was determined after carefully washing the soil with neutral methyl alcohol until the leachings were free from ammonium. The other set of samples was weighed into Erlenmeyer flasks, 100 c.c. of N/10 barium hydroxide added, the whole shaken occasionally for 18 hours, the contents then transferred to a Gooch crucible and washed with neutral methyl alcohol and then with neutral normal ammonium chloride. The barium was determined in the leachate, and the ammonium fixed by the soil was determined after washing the soil free of ammonium chloride with neutral methyl alcohol. The results are given in the following table:

TABLE VIII

Showing "Excess" Base Fixation from Barium Hydroxide and Barium Acetate

| Soil No. | Ba(OH) ₂ | | Ba(C ₂ H ₃ O ₂) ₂ | | Sum of Bases and Hydrogen | Sat. Cap. | |
|----------|---------------------|-----------------|--|-----------------|------------------------------|-----------|--------|
| | Ba | NH ₄ | Ba | NH ₄ | | Kelley | Parker |
| 1 | 74.3 | 25.7 | 30.1 | 22.9 | 25.6 | 25.4 | 25.0 |
| 2 | 140.0 | 51.4 | 48.0 | 47.4 | 40.3 | 51.7 | 51.9 |
| 3 | 118.3 | 50.8 | 50.7 | 45.4 | 40.4 | 48.3 | 48.3 |
| 4 | 90.1 | 62.1 | 65.4 | 62.3 | 63.5 | 63.6 | 63.5 |
| 5 | 27.3 | 14.1 | 16.3 | 14.1 | 14.5 | 13.9 | 15.4 |

Column 1 shows the barium fixed by the soils from an N/10 solution of Ba(OH)₂, column 2 the ammonium fixed by the same soils in displacing the barium with neutral ammonium chloride, column 3 the barium fixed from a neutral solution of barium acetate without preliminary treatment with the barium hydroxide, and column 4 the ammonium fixed by these same soils in displacing the barium with neutral ammonium acetate. In the last three columns the total replacement capacities of the soils, as determined by three different methods, are given for comparison. The comparative figures given in column 1 are significant. While it is admitted that it is impossible or very difficult to wash the soils free of barium with neutral methyl alcohol, where the soil has been treated with barium in solution as hydroxide, the greater absorption of barium hydroxide in the organic soils must be admitted beyond question. These soils, too, are the types which give the greatest variations between the replacement capacity determined by preliminary treatment with barium hydroxide and the replacement capacity calculated from the sum of the replaceable bases and hydrogen. The neutral soil, number 5, gives rather consistent results by all methods and shows the least absorption of barium hydroxide, from which we are led to assume that the high replacement capacity, denoted by preliminary treatment with barium hydroxide, is a characteristic of the acid soils. But the fact that the acid clay soils show less of this phenomena than the organic soils would further indicate that we have an error introduced, either by the organic matter or a difference in the properties of our acid clay soil colloids and the colloids in our acid organic soils.

In the following table there is shown a comparison of the total carbon content of the soil and the amount of base fixed in excess of the replacement capacity, and these results show an almost direct relation:

TABLE IX

Showing Relation of Organic Matter to Excess Base Fixation

| Soil No. | Total Carbon Per Cent | Excess Base Fixation |
|----------|-----------------------|----------------------|
| 3 | 13.60 | 67.5 |
| 2 | 9.69 | 88.6 |
| 1 | 4.99 | 48.6 |
| 4 | 3.00 | 28.0 |
| 5 | 1.22 | 13.2 |

Soil number 4, a heavy clay soil, with a very high exchange capacity, namely, 63.5 M. E., as well as the neutral clay, number 5, and the acid clay, number 1,

show a lower fixation of barium hydroxide than the organic soils 2 and 3. The fixation of barium hydroxide in excess of the replacement capacity is completely removed on subsequently leaching the soil with a normal solution of ammonium chloride, as shown in column 2 of Table VIII. Furthermore, the replacement capacity of the three clay soils, as determined by this method, closely agrees with the sum of the replaceable bases and hydrogen.

Barium carbonate precipitation can hardly be given serious consideration in view of the closely agreeing results obtained for the three clay soils of low organic content. The same should apply to the possibility of aluminates or inorganic basic salts as all the soils are similar in being laterite types and contain oxides and hydrates of iron and aluminum.

Hissink(3) has used barium hydroxide solution for estimating base unsaturation or replaceable hydrogen in soils. He used both conductrimetric titration and titration with indicators to determine the end point. His method is essentially as follows: A known weight of soil is placed in each of a series of Nessler tubes, to which are added varying amounts of standardized barium hydroxide solution. The tubes are immediately tightly stoppered and shaken several times daily for three days. The soil is then allowed to settle for one day and aliquots of the supernatant solution titrated against standard acid, using phenolphthalein as an indicator. The hydroxide absorbed is considered equivalent to the degrees of unsaturation of the soil.

The application of this method to Hawaiian soils only lends further evidence of hydroxyl absorption beyond unsaturation, or that some other secondary reactions are involved. This is shown in Table X, in which are given data obtained on soils numbers 1, 2 and 5. Five grams of soil were weighed into large glass test tubes, varying amounts of N/10 barium hydroxide added and the volume of water in each brought to the same volume of 100 c.c. They were then tightly stoppered, shaken several times daily for three days, allowed to settle one day, and 50 c.c. of the supernatant solution titrated with N/10 acid, using phenolphthalein as an indicator.

TABLE X
Showing Barium Hydroxide Absorption

| | | | | | |
|---|------|------|-------|-------|-------|
| Mgms. Ba(OH) ₂ added per 5 gms. soil..... | 42.8 | 85.7 | 171.4 | 257.1 | 342.7 |
| Mgms. Ba(OH) ₂ absorbed 5 gms. soil No. 1..... | 42.8 | 85.7 | 167.9 | 248.5 | 320.5 |
| Mgms. Ba(OH) ₂ absorbed 5 gms. soil No. 2 | 42.8 | 85.7 | 171.4 | 251.9 | 327.3 |
| Mgms. Ba(OH) ₂ absorbed 5 gms. soil No. 5..... | 39.4 | 78.8 | 137.1 | | |
| M. E. Ba(OH) ₂ added per 100 gms. soil..... | 10 | 20 | 40 | 60 | 80 |
| M. E. Ba(OH) ₂ absorbed 100 gms. soil No. 1..... | 10 | 20 | 39 | 58 | 74 |
| M. E. Ba(OH) ₂ absorbed 100 gms. soil No. 2..... | 10 | 20 | 40 | 59 | 76 |
| M. E. Ba(OH) ₂ absorbed 100 gms. soil No. 5..... | 9.2 | 18.4 | 32 | | |

This experiment indicates that not only is the organic matter present in the soil a function of "excessive" base or hydroxyl absorption, but that the concentration of the basic hydroxide solution, with which the soil is in contact, is an additional function. It is believed that no definite conclusions can be drawn from the application of the Hissink method to base unsaturation in Hawaiian soils.

In addition to the hydroxyl absorption shown in column 1, Table VIII, there is also some evidence in column 3 of barium fixation from neutral N/1 barium acetate solution in excess of the saturation capacity of the soil. This is indicated by the "excess" exchange capacity of all the determinations in column 3, and the fact that in the clay soils 1, 4 and 5, the ammonium fixed by subsequently leaching the soils, column 3, with neutral N/1 ammonium acetate agrees very closely with the exchange capacity of the soil, that is, the sum of bases and hydrogen. There is also a further interpretation of the data in Table VIII to the effect that a preliminary treatment of an acid or neutral soil with barium hydroxide is not necessary for a determination of the replacement capacity, but that it is possible to effect a complete saturation by leaching the soil with a basic acetate solution.

In order to investigate this more thoroughly, the organic soil, number 2, and the neutral clay, number 5, were subjected to a number of leachings with barium hydroxide. A description of these treatments is given as follows, and the data obtained are given in Table XI:

1. A ten-gram sample of soil was treated 18 hours with 100 c.c. of N/10 barium hydroxide, washed into a Gooch crucible, leached with 250 c.c. neutral N/1 ammonium acetate, then with neutral N/1 barium acetate and the ammonium determined in the leachings-A. Then leached with 250 c.c. N/1 ammonium acetate and barium determined in the leachings-B. Then leached with 250 c.c. N/1 barium acetate and ammonium determined in the leachings-C. Then with 250 c.c. N/1 ammonium acetate and barium determined in the leachings-D. Then with 250 c.c. barium acetate and ammonium determined in the leachings-E.

2. Treatment in this series was exactly as in 1, except that after the barium hydroxide treatment ammonium chloride and barium chloride were alternated in place of ammonium acetate and barium acetate.

3. Treatment in this series was similar to 1, except that barium acetate was used first after the barium hydroxide and then alternated with ammonium acetate.

4. Treatment in this series was exactly as in 3, except that barium chloride and ammonium chloride were alternated.

5. In this series there was no preliminary treatment with barium hydroxide. The soil was leached in a Gooch crucible with 250 c.c. neutral barium acetate, then 250 c.c. neutral N/1 ammonium acetate and barium determined in the leachings-A. Then with 250 c.c. N/1 barium acetate and ammonium determined in the leachings-B. Then with 250 c.c. N/1 ammonium acetate and barium determined in the leachings-C. Then with 250 c.c. barium acetate and ammonium determined in the leachings-D. Then with 250 c.c. ammonium acetate and barium determined in the leachings-E.

The barium determinations are all underlined in Table XI, while where the amount of ammonium fixed was determined the figures are not underlined. All data are calculated on a milliequivalent basis so that the replacement capacity is directly comparable in all. In all cases, between leachings, the soil was carefully leached with neutral methyl alcohol to remove the excess salt solution.

TABLE XI

Showing Comparative Absorption of Barium and Ammonium from Hydroxide and Acetate Solutions

| Soil Treatment | A | B | C | D | E |
|----------------|-------|------|------|------|------|
| 1 | 55.5 | 76.0 | 52.5 | 67.4 | 51.5 |
| 2 | 48.1 | 64.3 | 44.5 | 52.5 | 40.9 |
| 3 | 154.4 | 59.2 | 77.0 | 52.9 | 68.3 |
| 4 | 131.4 | 47.8 | 63.7 | 45.2 | 53.5 |
| 5 | 54.9 | 45.6 | 53.2 | 44.3 | 59.5 |
| 1 | 22.9 | 19.5 | 20.7 | 17.9 | 20.4 |
| 2 | 14.7 | 18.4 | 13.6 | 14.1 | 12.6 |
| 3 | 54.4 | 21.3 | 19.8 | 20.5 | 21.7 |
| 4 | 37.4 | 14.5 | 17.0 | 13.1 | 14.6 |
| 5 | 12.2 | 20.9 | 15.2 | 20.3 | 17.5 |

These data show that the soil will absorb larger amounts of base from barium acetate than from ammonium acetate, and that this absorption may be, at least in part, as barium hydroxide. For this reason ammonium acetate should be the more desirable salt for determining exchange capacity. The ionization constants for ammonium hydroxide and acetic acid agree very closely, which, as pointed out by Conrey and Schollenberger(1) makes this salt an ideal reagent. The fixation of barium as hydroxide from barium acetate is further indicated by the reaction of the leachates obtained in treating the organic soil in the above experiment. The soil, after 18 hours contact with N/10 barium hydroxide, and washing into the Gooch crucible with neutral methyl alcohol, and then leaching with neutral ammonium acetate, gave a reaction of pH 7.9 in the ammonium acetate leachings. On leaching this soil, then with normal barium acetate, pH 7.05, the leachings gave a reaction of pH 6.9 and, on subsequently leaching this sample with normal ammonium acetate, pH 7.0, the reaction of the ammonium acetate was increased to pH 7.2. An additional experiment was made in which 5 grams of this same soil were leached directly with 200 c.c. of normal barium acetate, pH 7.05, and the leachate was found to have been reduced in pH to 6.7. It was then leached with normal ammonium acetate, pH 7.0, and the leachate had a reaction of pH 7.1, while another leaching with normal barium acetate showed again a reduction of pH to 6.8 in the barium acetate leachate.

We believe we have sufficient data, therefore, to show that preliminary treatment of the soil with barium hydroxide is not necessary to obtain complete saturation, and the fixation of barium from a neutral solution of barium acetate will, like that from a preliminary treatment with barium hydroxide, show fixation in excess of the exchange capacity of the soil. It is recognized that the changes in reaction of the leachates recorded above are very small, but when one considers the low ionization of the acetate of a weak base the pH determination is not a good measure of the changes in potential acidity or alkalinity.

Page(5) has suggested that the replacement of hydrogen ions from the soil-absorbing complex can be carried to completion only by means of an alkaline solution. His suggestion is apparently based upon the fact that the soil complex associated with exchange reactions is salts of strong bases and weak acids and, therefore, more or less hydrolysis is essential for completion of the reaction. On this basis it occurred to us that in our two organic soils possibly we had not obtained complete replacement of hydrogen in the determination made by leaching with neutral barium acetate and titrating the leachate, then adding this to the replaceable bases to obtain the exchange capacity. But this does not harmonize with the fact that the replacement capacity of these two soils, as determined with barium acetate alone, is also greater than that obtained by the sum of the bases plus hydrogen, and agrees with the exchange capacity as determined by preliminary treatment with barium hydroxide. And that furthermore, all the methods when applied to the acid clay soils, one of which is just as high in hydrogen attached to the colloidal complex, give closely agreeing results between exchange capacity and what the capacity is shown to be by adding together the separately determined bases and hydrogen. Our results indicate that the peculiarities in fixing power of the organic soils is not a property of the colloidal zeolite, but rather of the organic matter. While our investigation has shown quite positive evidence of hydroxyl ion absorption, another property of organic matter should be mentioned as possibly being associated with the "excess" absorption of base. Some organic compounds or acids may form highly dispersed colloidal soils or slightly soluble salts with the monovalent bases, while with the divalent bases the salts are either well flocculated compounds like the divalent zeolites, or easily precipitated and entirely insoluble. The soaps of fatty acids may be mentioned as a case in point. We are led to suggest such organic compounds because on leaching the two organic soils with barium acetate, while the amount of barium fixed was greater than the replacement capacity of the soil it was quite consistent. On the other hand, on leaching these soils with ammonium acetate the amount of ammonium fixed, on milliequivalent basis, was less than the amount of barium and, too, the ammonium fixed was not so consistent as the barium.

The data offer a number of valuable suggestions for the quantitative determination of the saturation capacity of our soils. If it is desired to submit the soil to a preliminary treatment with barium hydroxide, then it will be of advantage that the subsequent leaching be made with a neutral normal solution of ammonium chloride. A normal solution of this salt will remove most rapidly the barium fixed as hydroxide, or other side reactions with the absorbing components of the soil, and leave in the soil only the ammonium ions fixed by the soil zeolites. This equilibrium appears to be approached more slowly with acetates or even with barium chloride after preliminary treatment with an alkaline solution, but may be determined accurately with ammonium acetate. The results indicate that a complete saturation of the exchange capacity should be possible through a single leaching with normal ammonium acetate, thus omitting the preliminary treatment with barium hydroxide. Conrey and Schollenberger(1) have already suggested such a method.

As thus applied to the five soils used in our investigation, the following results were obtained:

TABLE XII
Showing Replacement Capacity by Four Methods

| Soil No. | Replacement Capacity by Ammonium Acetate | Replacement Capacity by Sum of Bases and Hydrogen | Replacement Capacity Parker Method | Replacement Capacity Kelley Method |
|----------|---|---|---|---|
| 1 | 22.1 | 25.5 | 25.0 | 25.4 |
| 2 | 47.5 | 40.2 | 51.9 | 51.7 |
| 3 | 43.8 | 40.4 | 48.3 | 48.3 |
| 4 | 63.9 | 63.5 | 63.5 | 63.6 |
| 5 | 15.7 | 14.5 | 13.9 | 13.9 |

With the three clay soils the results agree quite closely. With the two organic soils, due probably to a solubility effect within the components associated with "excess" fixation of base, it was found to be difficult to obtain results that would check with each other. The two figures given in column 1 were arbitrarily selected from a number of determinations which varied from 38 M. E. to 55 M. E.

The conclusion appears inevitable that for our soils low in organic matter regardless of replacement capacity, a direct leaching without any previous neutralization of hydrogen ions with an alkali will give accurate replacement capacity values. But for soils high in organic matter it will be necessary to calculate the replacement capacity by a determination of the exchangeable bases and hydrogen separately. Leaching the soils with normal ammonium acetate, to which ammonium carbonate was added, was also tried on these soils. The results obtained checked very closely on the clay soils, but on the organic soils, 2 and 3, "excess" fixation was again noted. This lends further evidence that a strongly alkaline solution is not necessary for complete saturation when the leaching is made with ammonium acetate.

The methods which gave accurate results are summarized below:

Replaceable bases: Weigh 10 grams soil into a Gooch crucible, asbestos matted, and if a saline type leach with neutral alcohol, either methyl or ethyl, to remove soluble salts. Now leach with 250 c.c. of neutral normal solution of ammonium acetate. All leaching operations are conducted with filtering flasks using a slight vacuum. The entire leachate is then transferred to a porcelain casserole and evaporated on the steam bath to dryness. Ammonium acetate is completely volatile at steam bath temperatures. The residue is then taken up in dilute hydrochloric acid, and the bases determined by any standard methods. We prefer to use two separate 10-gram portions, one for calcium and magnesium and the other for sodium and potassium.

Replaceable hydrogen: Weigh either 5- or 10-gram samples into Gooch crucibles, depending upon the amount of replaceable hydrogen present in the soil, and leach with 250 c.c. of neutral normal barium acetate. Barium acetate is to be preferred to ammonium acetate, because in titrating the end point is more sensitive. The entire leachate is then transferred to a 400 c.c. beaker and titrated elec-

trometrically, using, preferably, the quinhydrone electrode. We prefer, in view of the buffering properties of acetates, to employ the following procedure: A chart or graph is prepared of ordinary coordinate paper with c.c. N/10 Ba(OH)₂ as abscissae and potentiometer readings in voltage or pH values as ordinates, or vice versa. The barium acetate to be used for leaching is adjusted to as near neutrality as possible, its pH or potentiometer reading determined, and at this point on the chart a horizontal line drawn. In titrating the leachates from the acid soils, the original potentiometer reading is taken. Tenth-normal Ba(OH)₂ solution is then added from a burette, one c.c. at a time thoroughly agitated after each, and the change in potentiometer reading or pH recorded. The data thus obtained are plotted graphically and the point where the curve cuts the horizontal voltage line of the neutral barium acetate is taken as the end point and, from this indicated number of c.c. N/10 Ba(OH)₂ used, the hydrogen ions are calculated. A number of determinations are given in Fig. 5 to illustrate.

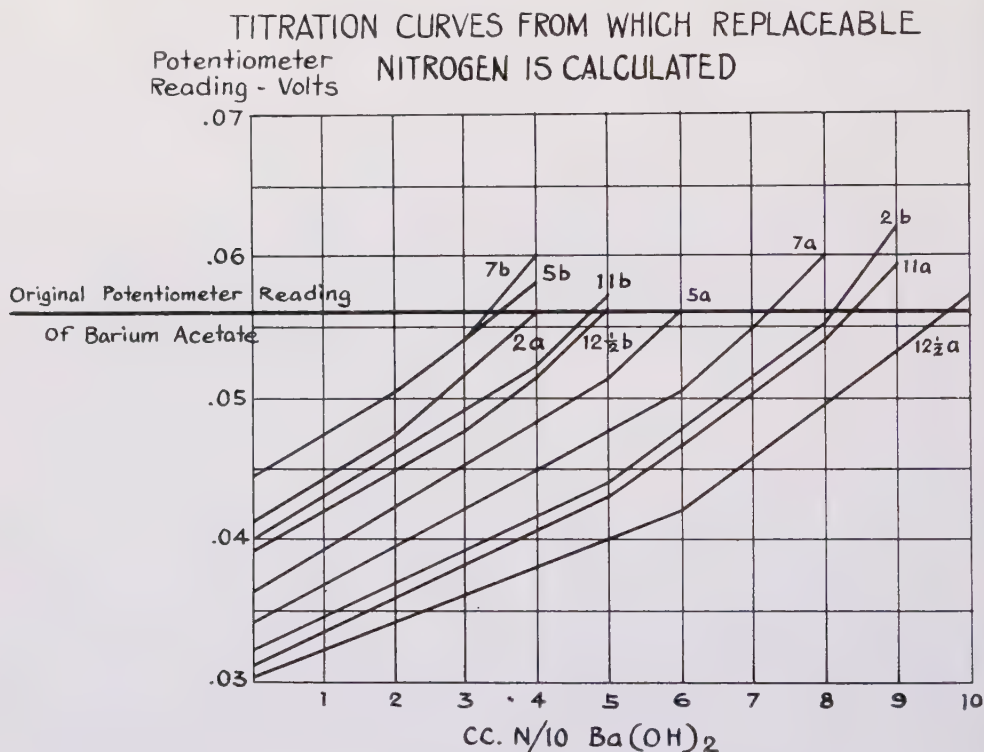


Fig. 5

Replacement capacity: For clay soils, weigh 5 grams of soil into a Gooch crucible and leach with 250 c.c. of neutral normal ammonium acetate. Wash free of ammonium acetate with carefully neutralized methyl or ethyl alcohol, and determine the ammonium fixed by the soil by distillation with magnesium oxide in the usual manner.

For highly organic soils the replacement capacity is best estimated by determining the total replaceable bases separately, or by the barium chloride method

outlined by Parker, and the hydrogen by displacement with barium acetate. The total replacement capacity is equivalent to the sum of the bases and hydrogen.

The above methods have been applied to a number of soils and subsoils taken from Kilauea plantation, and the results obtained are entirely satisfactory, as shown by the data given in the following table:

TABLE XIII

Showing Replaceable Hydrogen and Replacement Capacity, Kilauea Soils

| Soil No. | Replaceable Hydrogen | Replacement Capacity by Ammonium Acetate | Replacement Capacity Sum of Bases and Hydrogen |
|----------|----------------------|--|--|
| 2a | 4.0 | 17.2 | 21.4 |
| 2b | 8.2 | 14.3 | 16.2 |
| 5a | 6.0 | 14.0 | 15.0 |
| 5b | 3.8 | 7.1 | 8.4 |
| 7a | 7.3 | 21.3 | 26.0 |
| 7b | 3.3 | 9.2 | 10.4 |
| 11a | 8.2 | 17.2 | 18.2 |
| 11b | 4.8 | 10.3 | 10.0 |
| 12½a | 9.8 | 16.4 | 17.9 |
| 12½b | 5.0 | 9.8 | 9.0 |
| 14a* | none | 16.7* | 22.0* |
| 14b | 1.3 | 13.2 | 13.9 |
| 16a | 10.2 | 18.1 | 20.7 |
| 16b | 4.6 | 11.2 | 8.8 |
| 21a | 4.9 | 20.2 | 21.1 |
| 21b | 1.0 | 10.0 | 8.7 |
| 24a | 2.4 | 21.1 | 26.6 |
| 24b | 7.5 | 11.2 | 11.5 |
| 28a* | none | 16.9* | 22.1* |
| 28b | 8.0 | 13.6 | 12.8 |
| 33a | 7.8 | 27.2 | 29.8 |
| 33b | 10.6 | 16.0 | |
| 37a* | none | 18.4* | 26.2* |
| 37b | 4.7 | 11.7 | 10.6 |

Kilauea soils vary greatly in their degree of unsaturation with respect to bases, the least being 10 per cent and the greatest unsaturation being 65 per cent. There is also a wide variation in the total replacement capacity, namely, 27.2-14.0 M. E. in the surface soils, and 16.0-7.1 in the subsoils. The effect of coral sand is shown in Fields 14, 28 and 37, in which the hydrogen has been completely replaced by the calcium from the coral sand. It is very significant that in spite of the many years sand has been on these soils, the subsoils, the second foot, still contain active hydrogen ions. There is no correlation between either replacement capacity or degree of unsaturation and crop performance on these fields.

* Coral sand present in soil.

a Surface soil.

b Subsoil.

SUMMARY

The acidity of Hawaiian soils has been studied with special attention being given to the acid aluminum silicates. To these compounds are attached the so-called replaceable hydrogen ions.

Replaceable hydrogen is not readily displaced from Hawaiian soils by chlorides, but is readily and completely displaced by weakly dissociated acetates. Our soils are therefore high in so-called hydrolytic acidity, and low in so-called exchange acidity.

Replaceable hydrogen, in island soils, may be accurately determined by leaching the soil with neutral normal barium acetate and titrating the leachate, electrometrically, with N/10 alkali.

Our acid soils are apparently highly unsaturated, that is, unsaturated with respect to bases.

Some time has been devoted to studying the saturation capacity of our soils, that is, their capacity for fixing bases. The preliminary treatment of the soil with an alkaline solution is not necessary for complete saturation with base if the soil is leached with a neutral acetate solution. They will absorb barium in excess of their replacement capacity when in contact with a solution of a barium hydroxide.

The highly organic soils show a saturation capacity as measured by base absorption, which is in excess of the sum of fixed hydrogen, calcium, magnesium, sodium and potassium. Data are presented to show that organic compounds are associated with this excess base absorption.

The methods developed or selected from other investigations which were used throughout this work, and which gave very accurate and reliable results for replaceable hydrogen, replaceable bases, and replacement capacity, are given.

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Electrodialysis of Hawaiian Soils*

By W. T. McGEORGE

Electrodialysis was used by Cameron and Bell as early as 1905 in studying the mineral constituents of the soil solution. With revived interest in the phenomena of fixation and base exchange in soils, electrodialysis has recently commanded considerable attention, notably by Mattson(3), Bradfield(1), and Humfeld and Alben(2), in the United States as well as by several foreign investigators.

The apparatus used consists of a three-compartment cell, which may be made from an ordinary automobile battery sawed into three sections, each section being cut to a desired size to fit the purpose. These are then drilled to take either five or seven brass rods, so that the two outside chambers may be separated by the membrane enclosing the soil-water suspension and the whole cell clamped tightly to prevent leakage. Provision, of course, must be made for removing the dialysate. The apparatus is illustrated in Fig. 1.

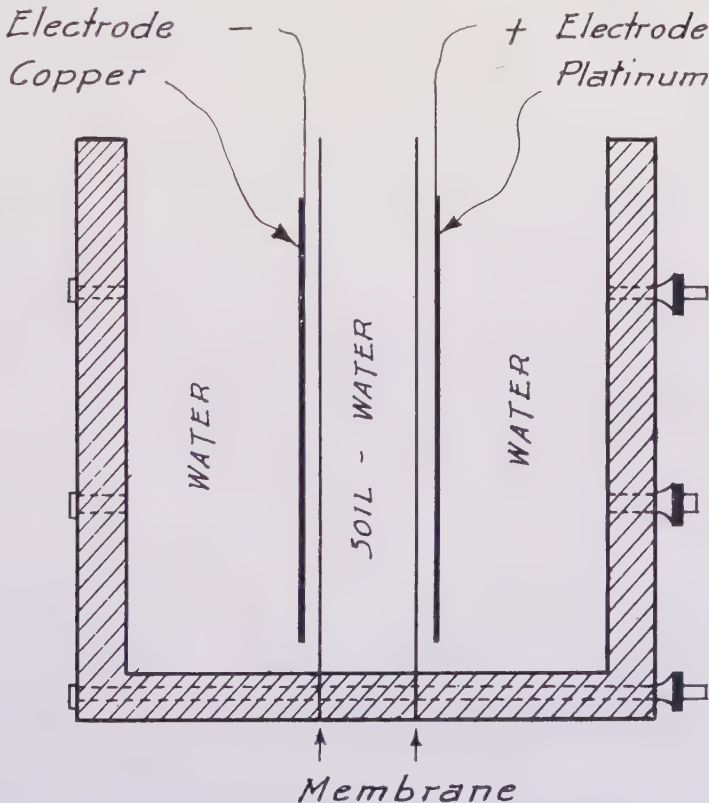


Fig. 1

* In an accompanying article on Availability of Potash, mention was made of the use of the process of electrodialysis for the study of plant food availability in soils. A large part of this work on electrodialysis has been devoted to potassium and is closely related to, and of interest in connection with, an accompanying article on Availability of Potash.

Of the dialyzable compounds present in soils the soluble salts, both the basic and acid ions, will dialyze readily, but the amount of these present in many soils is relatively small. In the main, the major part of the dialyzable material is derived from the less soluble compounds capable of hydrolysis and ionization, namely, the colloidal zeolites. The anion of the zeolite complex, being of colloidal dimensions, is too large to pass through the membrane and, therefore, only its bases are obtained by dialysis with the colloidal anion remaining within the membrane-enclosed chamber. This suggested electrodialysis as a means of studying and determining the zeolite absorbed bases, and it has been shown by both Bradfield(1), and Mattson(3), to give results agreeing closely with those obtained by replacing the bases with concentrated salt solutions. In view of this, we were interested to know how Hawaiian soils would respond to electrodialysis, especially the zeolite potassium as well as the potassium fixed from fertilizer applications.

A chamber of the type shown in Fig. 1 was prepared, using parchment paper as a membrane. For converting A. C. into D. C. a set of four cells was used, each composed of a lead and an aluminum electrode immersed in a solution of ammonium phosphate.* When connected with a 110 A. C. circuit, a current of 50-75 volts with an amperage of less than 1 was obtained in the dialyzing cell. Later, two Westinghouse rectigons and a rheostat were used and compared singly and together in series with the above rectifier.

EXPERIMENTAL

The soils selected for study included a number of island types of widely varying properties and were as follows:

- 3—26—A black clay soil from Ewa Plantation.
- 4—Kaneohe—An acid red clay loam from windward Oahu, low fertility.
- 5—MgZ—A black clay soil, Federal Experiment Station, high in magnesium zeolite.
- 6—A2D—An acid subsoil, Ewa Plantation Company.
- 7—2827—Field 28, Kilauea Plantation, experimental potash plot, received 1,500 pounds K_2O per acre from mill ashes, yellow clay soil, poor fertility.
- 8—2828—Check plot adjacent to 2827, received no potash.
- 9—2830—Field 28, Kilauea Plantation, check plot in a potash experiment, yellow clay soil.
- 10—2831—Potash plot, adjacent to 2830, 600 pounds K_2O per acre from mill ash.
- 11—2835—Field 25, Kilauea Plantation, check plot in potash experiment, yellow clay soil.
- 12—2836—Potash plot, adjacent to 2835, 1,000 pounds K_2O per acre from mill ash.
- 13—Waipio K—Potash plot from Experiment V, Waipio substation.
- 14—Waipio X—Check plot from Experiment V, no potash, Waipio substation.
- 15—Pahala—A very fertile soil, highly organic silt from Hawaiian Agricultural Co.
- 16—Hilo—A yellow acid clay from Hilo Sugar Co., which responds readily to potash.
- 17—19B—A red clay loam from Ewa Plantation, well supplied with available potash.

RATE AND AMOUNT OF DIALYZABLE BASES

In all cases 100 grams of soil were used for dialysis. The water was periodically removed from the outside chambers, usually after 2, 4, 6, 9 and 24 hours

* For the preparation of this apparatus as well as the dialyzing cell, the writer is indebted to W. W. Nichols, formerly of the sugar technology department.

and then every 24 hours until dialysis was complete. Each of these fractions was analyzed separately for calcium, magnesium, sodium, and potassium in order to obtain the rate of dialysis as well as the amount of dialyzable bases. In lieu of presenting the large amount of analytical data obtained in this experiment, the rate of dialysis is shown graphically in Fig. 2.

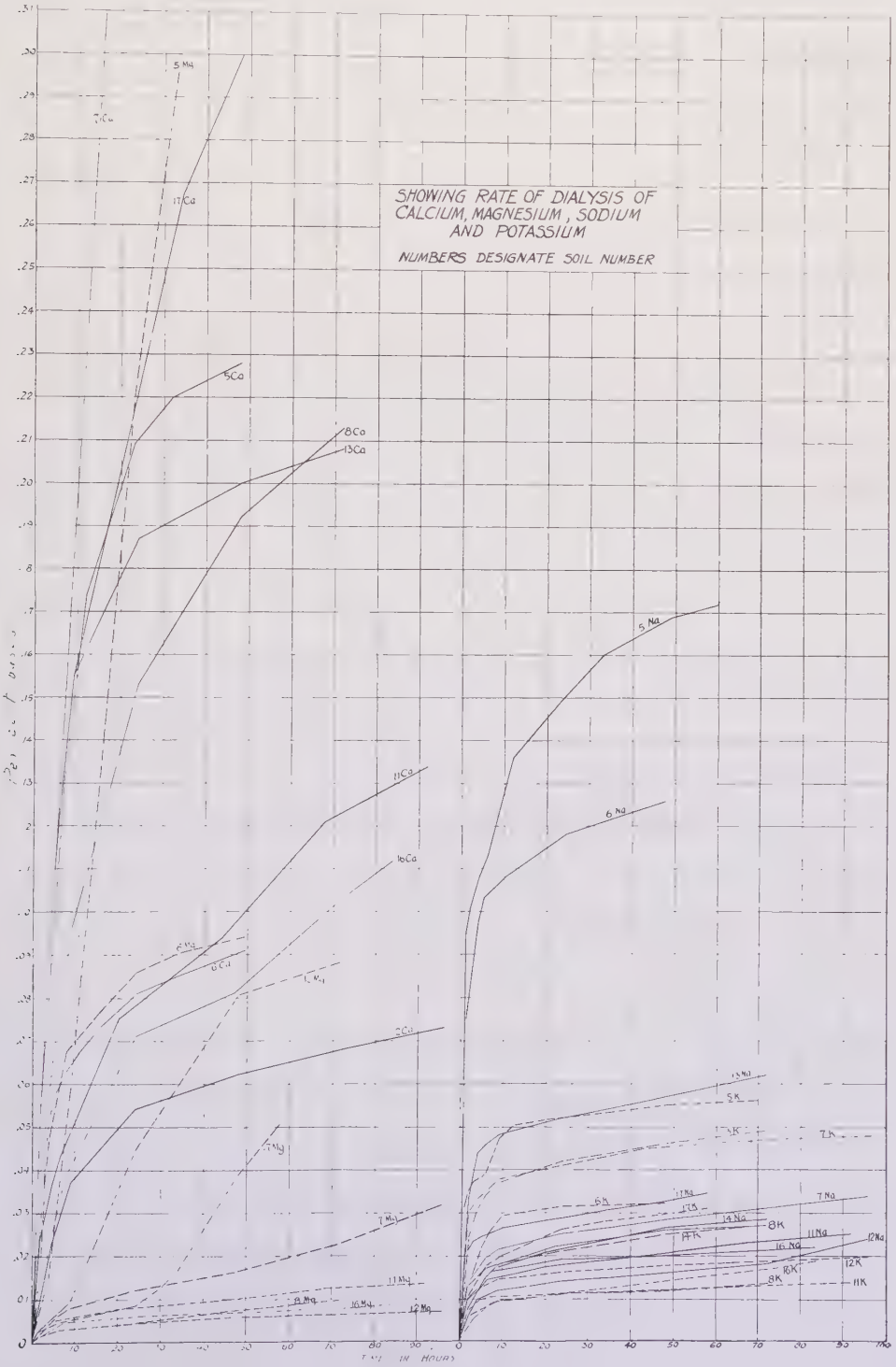


Fig. 2

It is evident from these graphs that practically all the sodium and potassium is removed within a period of a few hours, as shown by the rapidity with which the curves flatten out. While not as quickly removed as the sodium and potassium, calcium is nevertheless very rapidly dialyzed considering the excess of zeolite calcium that is present in all soils. On the whole, magnesium is removed very gradually. This may be due to the characteristic instability of magnesium hydroxide. All the bases in the cathode chamber are present as hydroxides, and the hydroxide of magnesium is only very slightly soluble unless ammonium salts are present in the solution. For this reason it is rather difficult to obtain an accurate measure of the rate of dialysis of magnesium where the magnesium content of the soil is high. It will precipitate upon the walls of the chamber, upon the electrode and upon the walls of the parchment. The slow dialysis of magnesium during the initial period of dialysis is peculiar to the neutral or alkaline soils, while in the acid soils it dialyzes more rapidly. This is because a certain hydrogen ion concentration is essential for holding the magnesium in solution until it passes through the membrane, hence, where other bases are present in large excess, these must first be largely removed to permit a rapid dialysis of the magnesium.

COMPARISON OF REPLACEMENT AND DIALYSIS

A comparison of the total bases removed by dialysis and by displacement is given in Table I and shows a rather close agreement, especially for the sodium and potassium. A number of the soils contained coral rock or coral sand, which has caused some disagreement in the calcium and magnesium determined by the two methods. But if these soils are not included the agreement is quite good. The data are sufficient to show that, as Bradfield and Mattson have previously stated, the dialyzable bases of soils are largely present as a part of the colloidal zeolite complex.

TABLE I

Showing Per Cent Zeolite Bases by Dialysis and by Displacement

| Soil No. | Calcium | | Magnesium | | Sodium | | Potassium | |
|----------|---------|--------|-----------|--------|--------|--------|-----------|--------|
| | Dial. | Displ. | Dial. | Displ. | Dial. | Displ. | Dial. | Displ. |
| 3 | .646 | .557 | .350 | .368 | .083 | .066 | .099 | .084 |
| 4 | .045 | .044 | .009 | .011 | .007 | .017 | .012 | .025 |
| 5 | .228 | .254 | .338 | .428 | .172 | .145 | .056 | .043 |
| 6 | .090 | .140 | .130 | .142 | .126 | .071 | .032 | .009 |
| 7 | .574 | .528 | .072 | .114 | .034 | .025 | .047 | .050 |
| 8 | .214 | .319 | .009 | .021 | .027 | .029 | .013 | .012 |
| 9 | .364 | .542 | .006 | .025 | .021 | .022 | .012 | .012 |
| 10 | .639 | .760 | .006 | .037 | .044 | .028 | .025 | .021 |
| 11 | .150 | .117 | .013 | .009 | .029 | .021 | .015 | .012 |
| 12 | .078 | .121 | .008 | .015 | .026 | .017 | .021 | .021 |
| 13 | .208 | .150 | .088 | .058 | .062 | .044 | .049 | .054 |
| 14 | .131 | .092 | .069 | .044 | .028 | .032 | .027 | .042 |
| 15 | .227 | .288 | .047 | .056 | .029 | .046 | .031 | .038 |
| 16 | .127 | .184 | .009 | .015 | .025 | .032 | .020 | .011 |
| 17 | .313 | .364 | .051 | .169 | .034 | .049 | .030 | .051 |

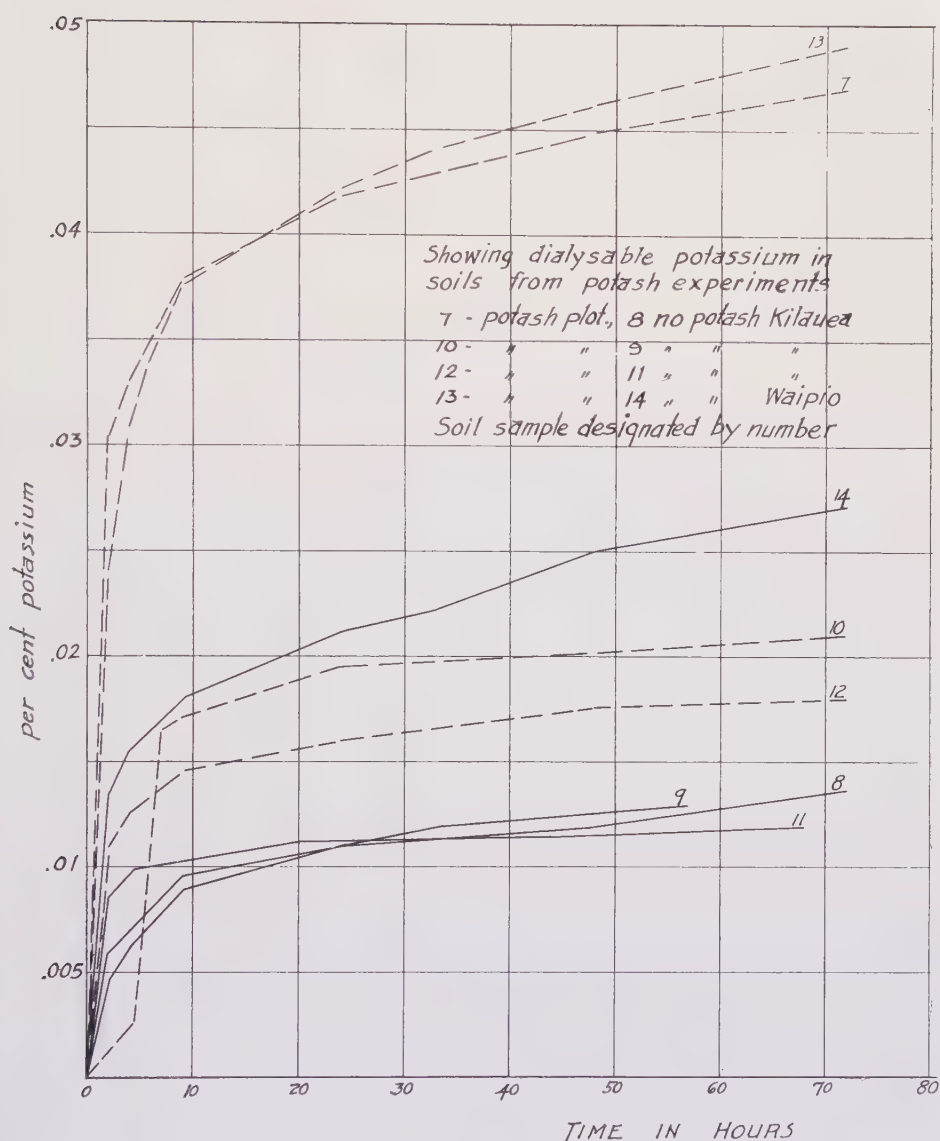


Fig. 3

In Fig. 3 are shown the rates of dialysis and the total amount of dialyzable potassium in the soils from the field experiments at Kilauea and Waipio substation. The potassium, which has been added in the fertilizer, is shown to have been fixed as a dialyzable compound, which is without question the zeolite, and confirms the results we obtained on these same soils by base replacement as well as the interpretations which were made. The conclusion is inevitable that the zeolite potassium present in Kilauea soils is just as active chemically to a replacement reaction, or the process of dialysis, as that in other island soils. Furthermore, the same holds true for the potassium absorbed by the soil after its addition as fertilizer.

Plants absorb inorganic salts only from the soil solution and the absorption is primarily, if not entirely, as ions. That is to say, if sulphate of potash (K_2SO_4) is added to a soil as a fertilizer, this salt will be dissolved in the soil solution and separate or dissociate, in part, as potassium ions (K)⁺ and sulphate ions (SO_4)⁻, preceding absorption by the plant. The absorption proceeds through the membrane surrounding the absorbing surface of the root, which is semi-permeable and to a degree selective, depending upon the needs of the plant. The phenomenon of potassium absorption, then, is largely one of dialysis. Therefore, it is not surprising that dialysis has been extensively employed in soil solution and plant nutrition studies, because all ions passing a semi-permeable membrane, such as parchment or collodion, are also capable of assimilation by the plant. The rate of dialysis, for difficultly soluble compounds is governed by the rate of hydrolysis and ionization of the compound and, where equilibrium is established at low concentration, the process proceeds very slowly.

If potassium sulphate is not entirely absorbed by the plant within a very short period following fertilization, the potassium ions will be fixed by the soil zeolites, in a form much less soluble than the sulphate. Upon the subsequent availability of this the plant is entirely dependent, otherwise it would be necessary to add soluble potassium fertilizer continuously to supply the needs of the crop. Under natural conditions potassium is present in the soil solution only in small amounts, and usually less than calcium, magnesium or sodium. It is apparent from this that the equilibrium concentration for potassium from zeolite is lower, or that the fixation is greater. Therefore, we cannot expect under normal conditions to find large amounts of potassium in the soil solution at any one time. Our interest, then, is centered upon the soil environment essential for increasing or maintaining the equilibrium concentration of potassium ion from zeolite.

The zeolite anion, with which the potassium is combined in its fixation, is not a soluble ion, being of colloidal dimensions and, therefore, the availability of the fixed potassium will depend upon several factors, notably the presence of other ions in the soil solution. For example, the equilibrium concentration of potassium may be increased by an exchange reaction between zeolite potassium and the base of another salt, which may be added in sufficient amount to disturb the equilibrium of the solution. Such a reaction, however, can only follow a fertilizer application or the addition of salts in the irrigation water. The common ions, on which the solubility of zeolite potassium largely depends, are not the basic ions but rather the acid ions such as nitrate and bicarbonate, which are supplied through the activities of the soil bacteria. Hence one value of active biological life in the soil.

We have shown that the Kilauea soils are well supplied with zeolite potassium, that is, as compared with other island soils. We have further shown this form of potassium to be actively displaced by other bases, readily dialyzable, and readily available, subject to favorable environment. In a separate investigation which we made of the biological activities in Kilauea soils, we obtained much evidence which proves that such activities were reduced to a minimum after the cane "covers in" and the soil temperatures are reduced. It seems fair to assume from these observations that this reduction in the biological life will result in a material lowering in the rate at which the elements will replace those drawn from the soil solu-

tion by the plant, and that what appears to be an ample supply of available potassium during the initial stages of crop growth will prove sorely deficient following the period at which the cane "covers in". That is to say, the potassium, which is fixed by the zeolite, when in contact with the soil solution, soon reaches by hydrolysis a definite equilibrium concentration. If free from the influence of outside factors, especially under Kilauea conditions, where the concentration of the soil solution is very low, the amount of potash in the soil solution will be very small at equilibrium, even where zeolite potassium is ample. This equilibrium concentration will be greatly increased if the soil bacteria are active and supplying the acid ions, nitrate and bicarbonate, which must draw on the zeolite bases for elements with which to combine. Thus the hydrolysis and ionization of the zeolite bases will be increased, as will also their availability. In a similar manner the carbon dioxide secreted by the roots will, in the form of bicarbonate, exert a pull upon the zeolite potassium, but unless root growth is very active the pull will not be sufficient to supply the needs of the aerial portion of the plant.

Potassium availability in Kilauea soils, then, appears to be largely a problem of increasing bacterial activities or stimulating root growth as a means of drawing the zeolite potassium away from the zeolite complex.

Our study of soil electro dialysis was primarily to obtain information on potash availability but, in view of the extensive application which it has found in soil science, we decided to study it more thoroughly while the opportunity permitted. The rectifier, which we used for converting A. C. into D. C., was a home-made apparatus, and, while serving the purpose excellently it required a great deal of attention to keep it in perfect operation. So, in order to compare the efficiency of this rectifier and determine the thoroughness of our dialysis, two Westinghouse* rectigons were obtained, a soil fairly high in all the zeolite bases was selected and was subjected to electro dialysis with a single rectigon, two rectigons in series, and with the aluminum-lead-ammonium-phosphate rectifier. With the latter and with the single rectigon, no resistance was necessary, so the rheostat was used only where the two rectigons were connected in series, and this in order to prevent heating within the dialyzing cell, which will result from using too strong a current. The data obtained by dialyzing under the above conditions are given in Table II and shown graphically in Fig. 4.

* 20 to 30 D. C. volts; 0 to .3 amperes; style 289417A.

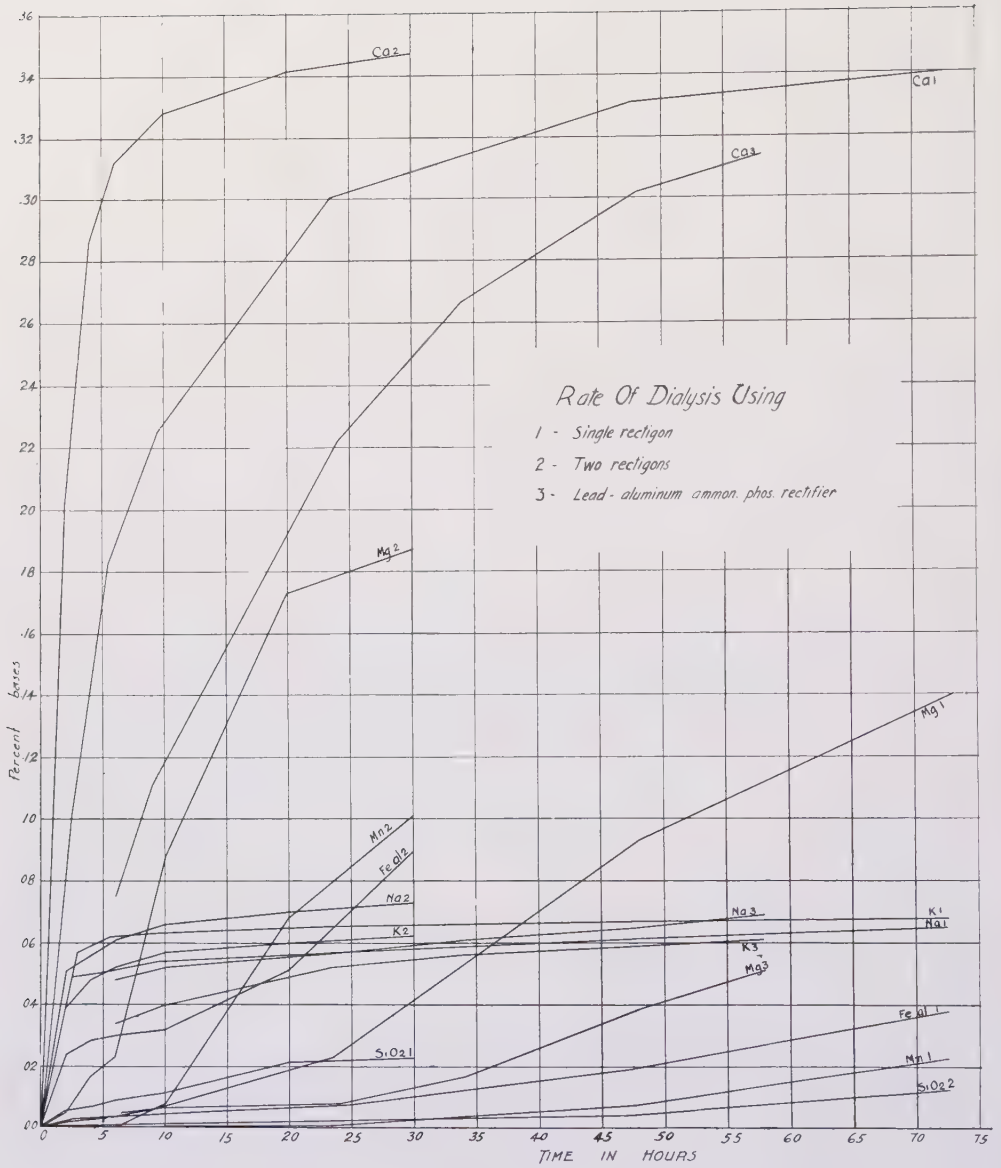


Fig. 4

TABLE II

Showing Rate of Dialysis and Total Amount of Bases Removed by Lead-Aluminum-Ammonium-Phosphate Rectifier as Compared With Standard Rectifier

| Time in Hours | Hydroxide in Cathode Chamber—c.c. N/10 HNO ₃ Required to Neutralize | | | Silica SiO ₂ | | Iron and Aluminum Oxides Fe ₂ O ₃ —Al ₂ O ₃ | | Maganese Mn ₃ O ₄ | | Calcium Ca | | | Magnesium Mg | | | Sodium Na | | | Potassium K | | | Volts | Amperes | Current * | | Volts | Amperes | | | |
|------------------|--|-----|------|----------------------------|-------|---|-------|--|-------|------------|-------|-------|--------------|-------|-------|-----------|-------|-------|-------------|-------|-------|-------|---------|-----------|---------|-------|---------|-----|-----|-----|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | | | Volts | Amperes | | | | | |
| 2 | 140 | ... | 43 | .0059 | ..... | .0240 | ..... | none | ..... | .2014 | ..... | .0388 | .0056 | ..... | .0028 | .0514 | ..... | .0328 | .0392 | ..... | .0198 | 33 | .59 | .. | ... | 46 | .32 | | | |
| 2.5 | ... | 81 | | | .0004 | | .0034 | | none | | | .1004 | | .0024 | | | .0488 | | | .0578 | | | 75 | .26 | .. | ... | 57 | .11 | | |
| 4 | 45 | ... | 12.2 | .0012 | | .0047 | | none | | .0852 | | .0204 | .0110 | | .0018 | .0050 | | .0034 | .0094 | | .0080 | .. | ... | 45 | .22 | .. | ... | 58 | .08 | |
| 5.5 | ... | 45 | | | .0007 | | .0005 | | none | | .0822 | | | .0014 | | .0050 | | .0024 | | .0034 | | .0068 | 77 | .26 | .. | ... | 58 | .08 | | |
| 6 | 14 | ... | 8.5 | .0020 | | .0016 | | none | | .0255 | | .0166 | .0162 | | .0004 | | .0028 | | | .0014 | | | .. | ... | 34 | .12 | .. | ... | 56 | .11 |
| 9.5 | ... | 22 | | | .0000 | | .0006 | | none | | .0433 | | | .0028 | | | .0028 | | | .0014 | | | 79 | .28 | .. | ... | 56 | .11 | | |
| 10 | 10 | ... | 19.0 | .0022 | ..... | .0017 | ..... | .0076 | ..... | .0160 | ..... | .0356 | .0560 | ..... | .0007 | .0048 | ..... | .0040 | .0056 | ..... | .0056 | 81 | .21 | .. | ... | 53 | .. | | | |
| 20 | 7 | ... | .... | .0102 | ..... | .0193 | ..... | .0605 | ..... | .0137 | ..... | ..... | .0848 | ..... | ..... | .0038 | ..... | ..... | .0014 | ..... | ..... | .. | ... | 36 | .11 | 53 | .13 | | | |
| 24 | ... | 33 | 49.5 | | .0000 | | .0028 | | .0007 | | .0754 | .1110 | | .0266 | .0023 | | .0036 | .0050 | | .0014 | .0114 | 80 | .15 | .. | ... | .. | ... | 62 | .09 | |
| 30 | 3 | ... | .... | .0011 | ..... | .0381 | ..... | .0338 | ..... | .0052 | ..... | ..... | ..... | ..... | .0083 | ..... | ..... | .0036 | ..... | ..... | ..... | .. | ... | .. | ... | 60 | .08 | | | |
| 34 | ... | ... | 20 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | .0298 | .0346 | ..... | .0602 | .0223 | ..... | .0038 | .0040 | ..... | .0026 | .0034 | .. | ... | 43 | .08 | 60 | .08 | | | |
| 48 | ... | 13 | 16.6 | ..... | .0032 | ..... | .0123 | ..... | .0069 | ..... | ..... | .0118 | ..... | ..... | .0121 | ..... | ..... | .0036 | ..... | ..... | .0022 | .. | ... | .. | ... | 66 | .07 | | | |
| 58 | ... | ... | 9 | | | | | | | | .0096 | | | .0458 | | | .0034 | | | .0010 | | | .. | ... | 44 | .07 | .. | ... | .. | ... |
| 72 | ... | 6 | | | .0082 | | .0182 | | .0147 | | | | | | | | | | | | | .. | ... | .. | ... | .. | ... | .. | ... | |
| Total..... | 219 | 200 | 178 | .0226 | .0125 | .0894 | .0378 | .1019 | .0223 | .347 | .341 | .314 | .1874 | .1392 | .0507 | .0734 | .0648 | .0588 | .0624 | .0686 | .0614 | | | | | | | | | |

* The voltmeter and ammeter readings were taken at

1—2 rectigons in series.

2—1 rectigon.

3—Pb-Al- (NH₄)₂ HPO₄ rectifier.

* The voltmeter and ammeter readings were taken at the end of each period of dialysis, just before removing dialysate for analysis.

The sodium, potassium and calcium agree quite closely. The dialysis of magnesium was not carried to completion and hence there is less agreement. This soil is an alkaline type and therefore gives up its magnesium very slowly. It is very evident that the lead-aluminum-ammonium-phosphate "set up" gave a D. C. current of required efficiency for the electro dialysis of soils. On the other hand the current supplied is so greatly reduced that dialysis is very slow. The efficiency of conversion, that is A. C. into D. C. also is probably far from perfect and therefore a limiting factor. The application of the single rectigon is limited by low current. By using two rectigons, in series, and adjusting the rheostat just sufficient to control the temperature in the dialyzing cell, dialysis will proceed very rapidly and will be complete in practically twenty-four hours. It will be noted that large amounts of iron, aluminum, manganese and silica, were dissolved from the soil when dialyzed with the two rectigons. This, however, does not appear to influence the zeolite bases or increase the amount of bases, but presents a question as to the effect of electro dialysis upon the absorbing complex of the soil.

EFFECT OF ELECTRODIALYSIS ON THE SOIL ZEOLITES

The large amounts of iron, aluminum, and manganese did not make their appearance in the dialysate until the calcium, magnesium, sodium, and potassium were almost completely removed. During the process of dialysis, as the zeolite bases are ionized and pass through the membrane, leaving behind the nondiffusible anion, hydrogen takes the place of the bases in the zeolite complex to form the acid or hydrogen zeolite. Therefore, as dialysis proceeds, the soil within the parchment chamber becomes increasingly acid. This hydrogen zeolite on hydrolysis and ionization, has a solvent effect upon the oxides and hydrates of iron and aluminum in the soil, which then, as ions, move toward the negative pole where, like the magnesium, they are precipitated as hydroxides. While this is the simplest explanation, it was not at all improbable that some of the dialyzable aluminum and silica were being formed by a destruction of the zeolite complex.

In the following table there are given the original reaction and the reaction of the same soils after the bases had been removed by dialysis:

TABLE III
Showing Reaction, pH of Soils Before and After Dialysis

| Soil No. | pH Before Dialysis | pH After Dialysis |
|-------------------------|--------------------|-------------------|
| 3 | 8.0 | 4.4 |
| 5 | 5.8 | 3.6 |
| 6 | 5.8 | 3.7 |
| 7 | 8.0 | 5.9 |
| 8 | 6.5 | 4.9 |
| 9 | 7.1 | 5.7 |
| 10 | 7.7 | 7.0 |
| 11 | 5.7 | 5.2 |
| 12 | 5.7 | 4.5 |
| 13 | 8.1 | 5.7 |
| 14 | 7.4 | 5.7 |
| 15 | 6.7 | 5.4 |
| 16 | 5.9 | 5.8 |
| 17 Pb-Al rectifier..... | 7.9 | 4.5 |
| 17 2 rectigons | 7.9 | 3.8 |
| 17 1 rectigon | 7.9 | 4.3 |

With the exception of one sample, No. 10, which contains a large amount of coral sand, there has been a considerable increase in acidity. All the above determinations were made upon the air-dried soil and in the dialyzed soil it was necessary to remove the soil from the chamber by washing with a stream of distilled water. The whole was then placed in a galvanized pan and allowed to evaporate and dry spontaneously in the air and exposed to sunlight. Knowing that air drying materially affects the reaction of Hawaiian soils, it is possible that the reaction of the soil within the dialyzing cell may have been, and probably was, more acid than indicated by the reaction in the above table. That the soils prepared as above were not completely unsaturated with respect to bases is shown by a comparison of the replaceable hydrogen and replacement capacity of the soils which were determined and calculated to a milliequivalent basis and are given in Tables IV and V.

TABLE IV

Showing Total Acidity, Reaction in pH, Hydrolytic Acidity and Exchange Acidity in Soils Before and After Dialysis, Expressed as Milliequivalent Hydrogen

| Soil No. | Reaction pH | | Total Acidity | | Exchange Acidity | | Hydrolytic Acidity | |
|---------------------|-------------|-------|---------------|-------|------------------|-------|--------------------|-------|
| | Before | After | Before | After | Before | After | Before | After |
| 3 | 8.0 | 4.4 | none | 33.2 | none | 23.9 | none | 9.3 |
| 5 | 5.8 | 3.6 | 8.9 | 50.0 | .6 | 38.9 | 8.3 | 11.1 |
| 6 | 5.8 | 3.7 | 4.0 | 19.0 | .2 | 12.1 | 3.8 | 6.9 |
| 7 | 8.0 | 5.9 | none | 11.1 | none | 1.0 | none | 10.1 |
| 8 | 6.5 | 4.9 | 4.8 | 17.7 | .4 | 2.9 | 4.4 | 14.8 |
| 9 | 7.1 | 5.7 | none | 15.4 | none | 1.4 | none | 14.0 |
| 10 | 7.7 | 7.0 | none | 2.8 | none | .6 | none | 2.2 |
| 11 | 5.7 | 5.2 | 8.8 | 14.0 | 1.0 | .7 | 7.8 | 13.3 |
| 12 | 5.7 | 4.5 | 8.0 | 16.0 | .6 | 1.7 | 7.4 | 14.3 |
| 13 | 8.1 | 5.7 | none | 13.6 | none | 1.8 | none | 11.8 |
| 14 | 7.4 | 5.7 | none | 13.7 | none | 2.4 | none | 11.4 |
| 15 | 6.7 | 5.4 | .... | 20.1 | .... | 3.1 | none | 17.0 |
| 16 | 5.9 | 5.8 | 18.7 | 25.6 | .2 | 1.4 | 18.5 | 24.2 |
| 17 Pb Al rectigon. | 7.9 | 4.5 | none | 19.4 | none | 10.1 | none | 9.3 |
| 17 2 W. rectigons.. | 7.9 | 3.8 | none | 26.7 | none | 16.3 | none | 10.4 |
| 17 1 W. rectigon... | 7.9 | 4.3 | none | 23.8 | none | 13.9 | none | 9.9 |

In order to determine the effect of dialysis upon the absorbing complex of the soil, the samples were, after dialysis and drying in the air, carefully examined as to the forms of acidity developed and the state of the replacement capacity of the soil. The so-called exchange acidity was determined by leaching 5 grams of soil in a Gooch crucible with 250 c.c. of neutral N/1 BaCl_2 and titrating the leachings with N/10 $\text{Ba}(\text{OH})_2$, using phenolphthalein as an indicator. The hydrolytic acidity was determined by leaching 5 grams of soil with 250 c.c. of neutral N/1 $\text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2$ and titrating the leachings with N/10 $\text{Ba}(\text{OH})_2$, using the quinhydrone electrode. The results are given in Table IV and shown graphically in Figs. 5 and 6.

In the original soils there is little exchange acidity, the hydrogen being present largely in hydrolytic forms. There is a close relation between soil reaction expressed as pH, and the amount of zeolite hydrogen, as shown by the similarity of the curves in Fig. 5.

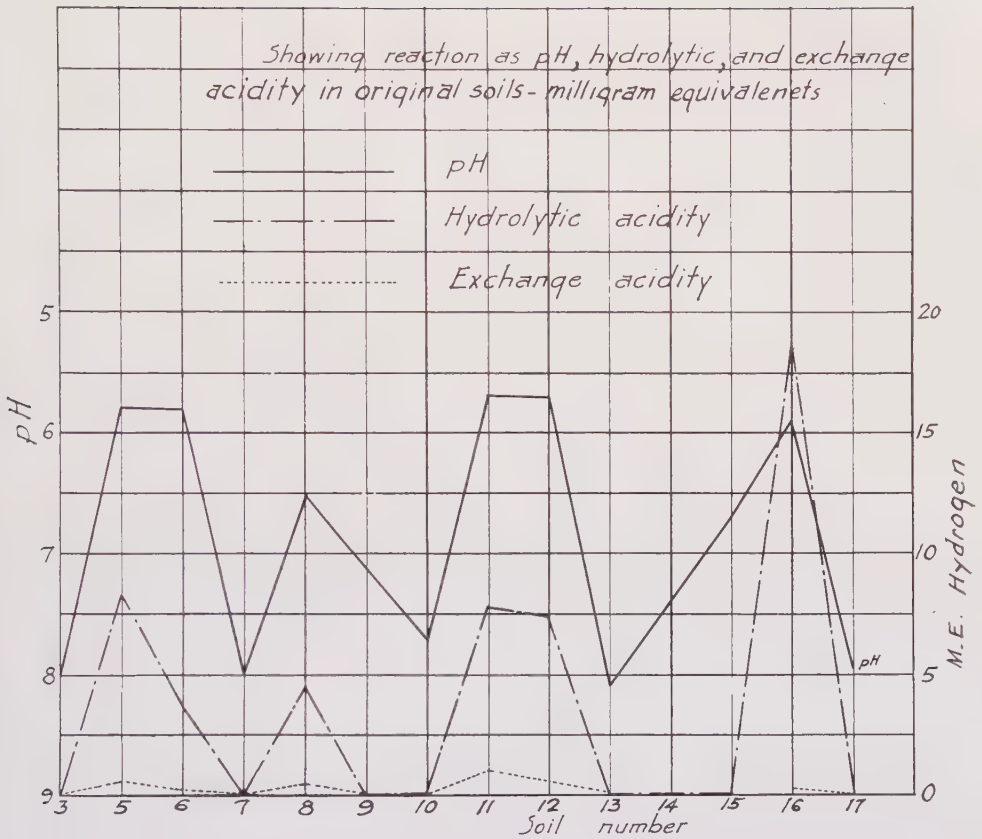


Fig. 5

The effect of dialysis has been to greatly increase both the exchange and hydrolytic acidity. The difference between the effect of dialysis upon the Kilauea soils, as compared to some of the other soil types, is of more than passing interest. In no case has a Kilauea soil shown more than a very slight fixation of hydrogen to form the so-called exchange acidity. This suggests a strong fixing power of the soil zeolites for hydrogen. A low solubility of zeolite potassium in 1 per cent citric acid likewise gave evidence of a strong fixing power in Kilauea soils. In work upon soil acidity it has been shown that the salt of a weak acid, such as barium acetate for example, will have a greater replacing power for soil acidity than the salt of a strong acid, such as barium chloride. The hydrogen displaced by the latter is referred to as exchange acidity and will include the acidity due to aluminum salts as well as a small amount of fixed hydrogen ions. Leaching an acid soil with a reasonable amount of a neutral solution of an acetate will give a complete and rapid replacement of all active hydrogen. In the data shown in Table IV and Figs. 5 and 6, total acidity represents the total amount of hydrogen ions present in replaceable forms and determined by displacement with barium acetate solution. The hydrolytic acidity is taken as the amount of hydrogen not displaced by 250 c.c. of N/1 barium chloride, or the difference between the total replaceable acidity and the exchange acidity. A very large amount of replaceable

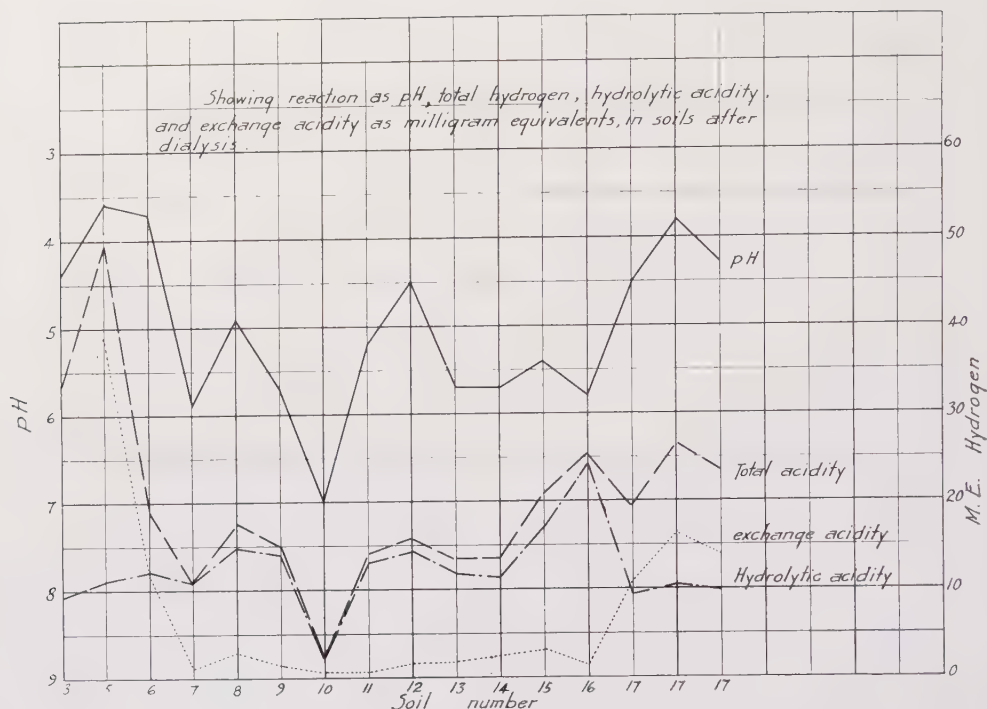


Fig. 6

hydrogen in the barium chloride leachings would indicate that the acidity is more active. In other words, that the hydrogen ion is more loosely held and therefore will hydrolyze and ionize more rapidly and to a greater concentration at equilibrium. On this basis we are led to suspect again a difference in the nature of the zeolites present in Kilauea soils. Their original hydrogen is present almost entirely as hydrolytic acidity, as is also the additional amounts of hydrogen absorbed during dialysis. The Waipio, Pahala, and Hilo soils, too, show a low fixation of hydrogen as exchange acidity. There is in this property much of interest. Several of the soils used in this series are characterized by unusually large amounts of zeolite magnesium, and it will be noted that in every case these types during dialysis fixed their hydrogen loosely, or in the form of the so-called exchange acidity. And vice versa, in every case where the soil was low in zeolite magnesium the exchange acidity was low, in fact almost negligible, and the hydrogen was fixed strongly and largely as the so-called hydrolytic acidity. In other words, the equilibrium concentration of hydrogen ions is greater in the dialyzed soils, which were originally high in zeolite magnesium. This property of the magnesium zeolites is shown in Fig. 7.

The question of the presence of iron, aluminum, and manganese in soils, as exchangeable components of the absorbing complex, is still more or less an unsettled issue. On the other hand, it is definitely known that the nondiffusible "acidoid" anion of the absorbing complex is largely an alumino-silicious complex. The appearance of these elements in such large amounts in the products of dialysis could easily be taken as an indication of the destruction of the zeolite, which is

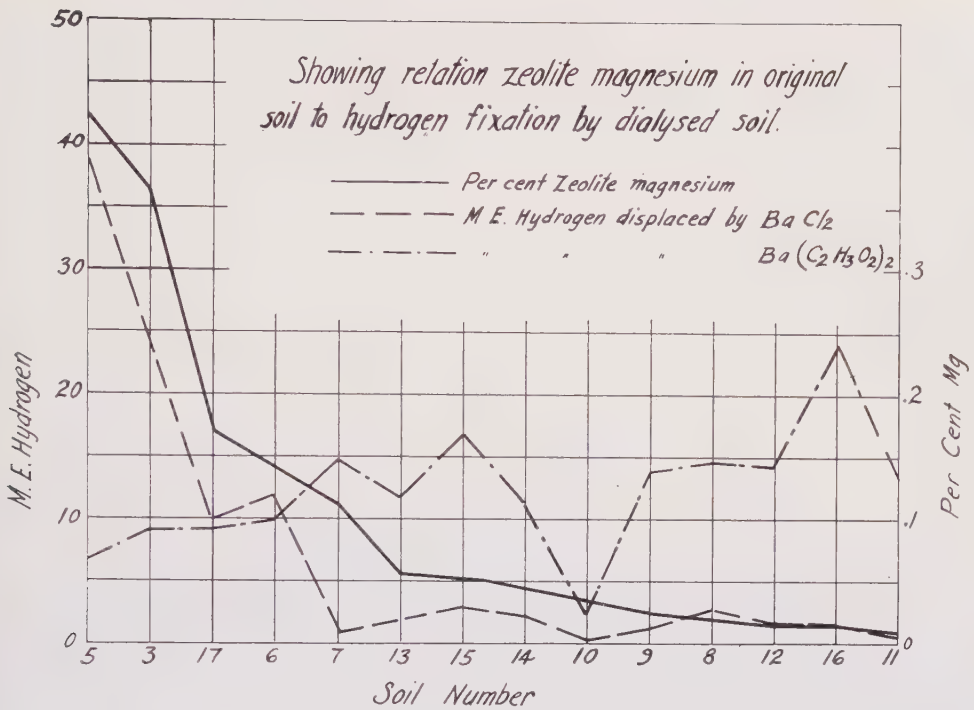


Fig. 7

known to be more or less unstable under certain conditions. A destruction of zeolite would materially reduce the exchange properties of the soil and thereby greatly affect its exchange capacity. So, in view of the fact that only negligible amounts of aluminum, manganese, or iron have appeared in the displaced solutions of our soils, we suspected a destruction of the zeolite complex, at least in part.

To determine this, the exchange capacity of the soil, before and after being subjected to dialysis, was determined. The results are given in Table V.

TABLE V

Showing Exchange Capacity of Soils Before and After Dialysis—Results Expressed in Terms of Milliequivalents per 100 Grams

| Soil No. | M. E. Before Dialysis | M. E. After Dialysis |
|------------------------------|-----------------------|----------------------|
| 3 | 62.8 | 62.2 |
| 5 | 63.5 | 61.9 |
| 6 | 20.9 | 25.1 |
| 7 | 23.2 | 21.1 |
| 8 | 19.1 | 20.6 |
| 9 | 29.4 | 27.1 |
| 10 | 22.8 | 21.5 |
| 11 | 16.7 | 16.9 |
| 12 | 16.4 | 17.3 |
| 13 | 18.4 | 16.7 |
| 14 | 16.8 | 15.7 |
| 15 | 32.4 | 35.9 |
| 16 | 30.8 | 29.5 |
| 17 Pb-Al-rectifier | 31.6 | 31.0 |
| 17 2 W. rectigons | 31.6 | 32.0 |
| 17 1 W. rectigon | 31.6 | 31.4 |

It is evident from the above that the iron, aluminum, and manganese were not derived from the zeolite, but rather were dissolved by the action of the hydrogen ion upon the hydrates and oxides present in the soil. And from the above one would be inclined to question the presence of these elements, iron as ferric, in replaceable forms in soils, especially on observing the results obtained on soil 17. Using the strongest current, two rectigons, which brought into solution .022 per cent silica, .089 per cent iron and aluminum oxides, and .1019 per cent manganese oxide, there was absolutely no change whatever in the exchange capacity of the zeolite in this soil. Since this stability of the zeolite complex was shown in all the soils subjected to electrodialysis, we are forced to recognize a highly stable exchange colloid in our soils.

SUMMARY

The effect of electrodialysis upon Hawaiian soils has been studied from the standpoint of its relation to the availability of calcium, magnesium, potassium and sodium naturally present in the soil and the potassium added with the fertilizer.

The stability of the colloidal soil zeolites, as affected by electrodialysis, has also been given some attention.

The amounts of calcium, magnesium, potassium and sodium removed by electrodialysis are quite definite and agree with that determined as exchange bases by displacement with salt solutions.

Potassium added as fertilizer is fixed by the soil colloids in a readily dialyzable form.

An apparatus and method have been described which, when using two Westing-house rectigons in series, and controlling the temperature in the dialyzing cell by means of a rheostat, a rapid and accurate dialysis of the soil may be made.

It has been shown that on subjecting the soil to electrodialysis by the above method, there will be a notable solubility effect toward iron, aluminum and manganese present in the soil as oxides or hydrates, but that this is not associated with any destruction of the absorbing complex of the soil.

There is some evidence given that the fixing power of the zeolite for hydrogen is in some manner influenced by the magnesium content which it originally possessed. Zeolites, which were high in magnesium, appear to possess the property of fixing hydrogen in more easily replaceable forms, namely, the so-called exchange acidity.

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Some Chemical Reminiscences*

By DR. L. L. VAN SLYKE

First, I am going to say something about the pioneer days of chemistry in Hawaii. In 1884, I was invited to come to Honolulu to teach in Oahu College at Punahou, and to serve as chemist for the Hawaiian government, a position then newly created. The Rev. Dr. C. M. Hyde, secretary of the Board of Trustees of Oahu College, wrote to one of the professors of the University of Michigan, asking that he be put in touch with some young man who would consider a position in Honolulu as teacher of chemistry. This letter was turned over to Dr. Prescott, head of the department of chemistry, in which I was an instructor. Dr. Prescott handed me the letter with an enigmatic smile and the remark that I might be interested in the proposition.

After reading the letter, my first reaction was geographical—Where is Honolulu? On recalling my early school training, I decided that it might be in the West Indies, or, perhaps, in the remote and little-known Sandwich Islands. An atlas confirmed the latter supposition. As a result of ensuing correspondence, it was finally arranged that I should begin work in September, 1885.

The little building on Punahou campus, known as Bishop Hall of Science, had just been completed and awaited my arrival for proper equipment. Some months before, I had ordered chemicals and apparatus, largely from Germany, and these arrived in November. Among these supplies was a Westphal balance, which, I learn, is still doing good service. The source of laboratory heat was a special gasoline burner and a gasoline stove for student use. I never ceased to be nervous over the possibility of a blow-up, but we were evidently under the protection of a special providence.

Bishop Hall of Science made possible for the first time the use of laboratory methods in teaching chemistry in these Islands. There were many interesting, and some amusing, experiences but time does not permit details in regard to the teaching work.

You may be interested to know what were some of the kinds of work which the government called upon its chemist to do. The first case was a sample of "moonshine" liquor, which some Chinaman had been caught making. You will notice that bootlegging in Hawaii is not an exclusive development of recent times. The Marshal of the Kingdom, who was the general grand sheriff of the Islands, brought the sample. He still survives in the person of General J. H. Soper, who, after he ceased to be Kalakaua's marshal, helped make history in the troubled days of the birth of the Republic of Hawaii. Analysis showed the sample of "moonshine" to contain 40 per cent of alcohol.

His Majesty King Kalakaua was interested, from time to time, in having various materials examined. The first sample was a pretty crystal of iron pyrites.

* Address delivered before the Hawaiian section of the American Chemical Society, Honolulu, May 16, 1929.

He was undoubtedly disappointed to learn that his find was not a high-grade nugget of pure gold. The chemist did not include in his official report the statement that the common name of the material was "fool's gold".

Another sample was a piece of anthracite coal, which was picked up on Kalakaua's cattle ranch, located on the present site of Schofield Barracks. It was easy to identify the material, but not so easy to tell by what accident it came to be where it was found.

His Majesty must have been disappointed and discouraged in his earnest efforts to get scientific help in developing the mineral resources of his kingdom, particularly in relation to mines of gold and coal. I presume he came to regard the government chemist as an unprofitable servant.

In consultation with two of the trustees of Oahu College, Sanford B. Dole, then practicing law here, later Hawaii's "Grand Old Man," and A. F. Judd, Chief Justice of the Supreme Court of Hawaii, father of Lawrence M. Judd, Hawaii's next governor (who had not then been born), it was decided that a chemical survey of the various sources of domestic water supply of Honolulu should be made. This was carried out during the months of February, March, and April, 1886; and the report of the investigation was published in the biennial report of the Minister of the Interior to the Legislative Assembly of 1886 in the thirteenth year of the reign of His Majesty Kalakaua. Over twenty samples of water were collected, with the assistance of the superintendent of the city water works, Mr. Chas. B. Wilson, who later gained notoriety as an evil genius behind the throne in the reign of Queen Liliuokalani.

The main water storage was a reservoir at Luakaha, up Nuuanu Valley, and a filtering reservoir lower down. This was supplemented by Kapena Spring and, in addition, several artesian wells located at Waikiki, Pawaa, Thomas Square, Palace Square and Makiki. These analyses were the first made of Honolulu waters. While the methods of water analysis in 1886 were not as satisfactory as those of today, and the methods of bacteriological analysis of water had not been developed, the results were, in general, fairly reliable in identifying really dangerous water. The results of this first chemical survey of Honolulu's domestic water supplies indicated that the water was in a good to fair sanitary condition, with the exception of that of the Thomas Square artesian well, which was seriously contaminated with impure surface water. This abnormal condition led the superintendent of water works to do some investigating and he discovered a leakage of water from an abandoned concrete reservoir, located just below Makiki Valley, the pipes of which had not been disconnected from the Thomas Square district. After the water of the Makiki reservoir was completely shut out, a later examination showed a normal condition. One other point of interest was the difference in softness between the water of the artesian well at Waikiki and the other wells in the city. The Waikiki water was much softer, due to the presence of sodium bicarbonate.

I will refer to only one other form of chemical activity in Hawaii in those days, my relation to the agriculture of the Islands. Some of the sugar planters began to be interested in the possibilities of getting some help from the application of chemical knowledge to a study of their problems. Only one attempt had

been made previous to 1885 to get such help. Claus Spreckels was at that time a commanding figure in the sugar industry. He had in his employ in his San Francisco refinery a German chemist, who had become a victim of fondness for alcohol. This chemist was transferred, as a reform measure, to the Spreckels plantation on Maui, but was so rarely sober that he was finally turned loose on the community as a consulting analyst. One of the planters related an experience with this agricultural chemist, who visited his plantation, took samples of soil and reported the results of analysis the next day, recommending a fertilizer formula, for which a generous fee was charged. I never had the privilege of meeting this fellow chemist. He was the first representative of agricultural chemistry in Hawaii, but we would hesitate to regard him as the first representative agricultural chemist.

Soil analysis was then in a very elementary stage and I was providentially saved by my inexperience, modesty, and lack of equipment from wasting time in analyzing soils under the then existing conditions. However, I became the first teacher of agricultural chemistry in Hawaii, without intending to. Henry M. Whitney, the postmaster general, was also editor and, I think, founder of the *Planters' Monthly*. He persuaded me to write a series of articles on agricultural chemistry. I know that the articles were reliable because they were made up from Johnson's *How Plants Feed* and *How Crops Grow*, Ville's *Mamures* and some other standard books of the time, which I had fortunately included in my personal library, which I brought with me to the Islands. This was the first course in agricultural chemistry to be taught here. For a young man, I believe that I was reasonably conservative, and I have the present satisfaction of believing that the course of instruction did not result in any serious damage to the progress of agriculture.

A few years later, after I had left the Islands, Mr. Whitney wrote me of the purpose of the Planters' Association to secure a chemist and asked me to suggest some one. I referred him to Dr. Wiley, chief of the Bureau of Chemistry, of the United States Department of Agriculture. This suggestion resulted in the engagement of Dr. Maxwell and the beginning of the gradual development of the Hawaiian Sugar Planters' Experiment Station.

The Bishop Hall of Science may properly be regarded as the pioneer chemical laboratory in Hawaii. To what extent this institution developed a chemical trend of thinking and was influential in starting the train of circumstances, which has resulted, in the course of forty years, in the splendid research organizations which we find here today, who can say? The chemists of Hawaii have made very notable contributions, not only to the solution of many of the problems peculiar to the local conditions, but also substantial, valuable additions to the knowledge of agricultural chemistry in a broader way.

The history of the pioneer days of chemistry in Hawaii would not be complete without the mention of Dr. Stangenwald. He was a physician, of German birth and training, and for many years one of the most successful practitioners here. He had his hobby in chemistry and accumulated physical and chemical apparatus and supplies in great variety and quantity. He kept his chemical work and his purposes completely to himself. Nobody knew what he was doing or

trying to do, and so there were numerous surmises. One guess was that he was trying to chase that old will-o'-the-wisp, the Philosopher's Stone, in order to transmute common metals into gold. Nobody knew; everybody wondered and guessed. He died without ever taking anyone into his confidence. I met Dr. Stangenwald once while I was here, not long before I left the Islands in 1888. He was a man of attractive personality. On this one occasion he showed no inclination to talk about chemistry in general or in particular. When I was visiting here in 1915, I was asked by his niece, Mrs. Nellie Waterhouse Wood, one of my Punahou pupils, who had inherited Dr. Stangenwald's property, to look over the library and laboratory equipment, occupying several rooms, in order to advise her what to do with it all. The chemical part of the library consisted of German and French publications of the day, furnishing no clue as to his line of work. The apparatus, chemical and physical, consisted of many kinds in large quantities, electrical apparatus, various kinds of furnaces, etc. Dr. Dillingham tells me that the University acquired much of the collection and he can tell you more about its details than any one else. Dr. Stangenwald was the mystery man of his day in Honolulu. Whether he could have contributed anything to chemical knowledge, if he would, no one can ever know.

The far-reaching changes that have taken place in Hawaii in the last forty years in the application of chemistry to Island problems, mostly agricultural, are typical of the changes that have come in every phase of life here. Then the total population of the Islands was 80,000 and of Honolulu 20,000. Punahou was in the remote outskirts of the city. The region right here where the University is located was an uncultivated, if not a howling, wilderness, accessible only by bridle paths.

There were traffic problems even then. At night every vehicle had to carry a light. The aristocratic had carriage lamps; the plain citizen hung an oil lantern to the front or rear axle of the vehicle. Saddle horses were not required to carry tail lights. Otherwise the streets were not illuminated.

Salaries have changed also. As an instructor in the University of Michigan, I received \$600 a year. Full professors there received \$2000. When, therefore, I received an offer of \$2000 to come to Honolulu, it looked like a princely income. Toward the end of the three-year term of service, for which I had contracted, I began to feel strongly the isolation from contact with fellow chemists. I decided to return East.

The school year of 1888-9, I spent in teaching at the University of Michigan and then carried out a long-cherished plan of spending a year in study with Dr. Ira Remsen at Johns Hopkins University. During my year in Baltimore, I visited Washington and there met for the first time Dr. Harvey W. Wiley, chief chemist of the United States Department of Agriculture.

I want to tell you something of these two men, especially as I came to know them by personal contact. Remsen and Wiley were pioneer leaders in the chemical activities of America. One was the ideal teacher and research worker in pure chemistry; the other was the leader in chemistry applied to agriculture and to pure food control. Each exercised a profound, lasting and helpful influence on the development of chemistry in its pure and applied phases. Remsen was born and

educated in New York City. Wiley was a product of the middle-west environment. Both studied medicine and received the degree of M. D. Remsen was a teacher a large part of his life; Wiley, for several years. They were contemporary, Wiley having been born in 1844 and Remsen in 1846.

In his medical course, Remsen was deeply impressed with the superficial knowledge of chemistry acquired by medical students and of the slight value of such meager knowledge in the practice of medicine. He had, however, acquired enough of a taste of chemistry to lead him to decide that he did not want to practice medicine, but that he did want to learn something about chemistry. He used to say that about the only thing he retained in memory from his first course in chemistry was the statement made by the professor in the medical college that old shirts could be changed into sugar. He felt that chemistry was a wonderful science, about which he knew nothing but wanted to learn.

At that time (1867), it was necessary to go to Europe for an adequate training in chemistry. Remsen first went to Munich to study in Liebig's laboratory, where, under Volhard, he gained his first systematic training in methods of analysis. Liebig himself had given up instruction of students. Remsen became particularly interested in organic chemistry and so went from Munich to Goettingen, at Wöhler's suggestion, to begin research under Fittig. After studying for three years in Germany, he gained the degree of Ph. D. in 1870. The two years following he served as Fittig's assistant at Tübingen. There he began the study of aromatic sulfonic acids and their derivatives, a field of research that held his attention throughout his life.

Returning to the United States, Remsen became professor of chemistry and physics in Williams College. It was a year before he could get a laboratory equipped for his own research work. It sounds strange in this day to learn that he worked in an environment not only unsympathetic but even hostile to experimental science. He, however, succeeded where others had failed. Realizing the need of better methods of teaching chemistry, he purposely concentrated his attention on the art of imparting knowledge. Remsen attracted attention, while at Williams College, by the publication of early research work, and especially by the publication of his *Theoretical Chemistry*, which brought together, in a unified whole, important fundamental principles of chemistry and made clear their relationships in a simple and attractive way.

When President Gilman, in carrying out his ideal of establishing a university based on scholarship and research, looked about for a man to head a department of chemistry at Johns Hopkins University, his choice logically fell on Ira Remsen, who began his epoch-making work there in 1876. In an incredibly short time, Johns Hopkins became the mecca of young men desiring the best available training in chemistry, for both teaching and research. In the course of ten years, Johns Hopkins Ph. D.'s in chemistry were filling many important teaching and research positions in American colleges and universities. Through his work as teacher, his leadership in research, his authorship of model text-books and his editorship of *The American Chemical Journal*, Remsen was easily, for a generation, the greatest force in America in promoting chemical knowledge and research of the highest quality. In no small degree must we attribute to Remsen's initial

influence the powerful impetus which chemical research in America has attained today. I have given this brief survey as a preliminary to what I have to say about my personal contact with Ira Remsen.

As I have already said, I went, one year after leaving Hawaii, to spend the college year of 1889-90 in study with Dr. Remsen, it being my intention at that time to devote my life to the teaching of chemistry. It is somewhat aside from chemistry, but it may be of interest, in passing, to say that I carried to President Gilman a letter of introduction from Judge Lawrence McCully, one of the associate justices of the Supreme Court of Hawaii, and a classmate of President Gilman's at Yale. Incidentally, I may add that the next governor of Hawaii was named after Lawrence McCully.

I attended all of the lectures which Remsen gave, both elementary and advanced, inorganic and organic. He was, in every way, an ideal teacher. The class room teaching was by lecture. The illustrative class room experiments, performed during lectures, were perfect in every detail and served as real factors in the teaching process. His choice, finished phraseology, his ease, smoothness and fluency, his simplicity of expression, his clarity of reasoning, his vividness of description, his occasional flash of pertinent wit, all combined to give his lectures an indescribable charm and a feeling of intellectual satisfaction to the listener. I always felt as if I were in the presence of a master mind.

It was a special privilege to hear him speak on the history of chemistry. He had come into close personal contact with many of the pioneer men who had developed modern chemistry. He gave me the feeling of knowing the men personally myself, as he told of Wöhler, Liebig, von Baeyer, Wislicenus, Bunsen and others. He made their personalities vivid and fascinating. In these lectures, there were mingled with science a delightful philosophy and a keen sense of humor.

Each week there was a journal meeting for graduate students, in which Remsen reviewed with his characteristic analytical clarity the articles of special interest. Individual articles were also assigned to the students for review in practice.

At one of these journal meetings, in going over a pile of journals, he picked up a small, thin, insignificant-looking pamphlet. He said, "This is the last number of the *Journal of the American Chemical Society*. It hasn't a single article in it of the slightest value. Under its name, it is a disgrace to America, as the presumable representative of this country," and he slammed it down on the table with an expression and gesture of supreme contempt. His feeling was justified at the time. It was not long after, however, before some vigorous young men put themselves at the head of the society and began energetic work to develop it into the powerful organization which it has become. About twelve years after this, Remsen, became president of the American Chemical Society. Some years later, when his duties as president of Johns Hopkins University absorbed his entire time, he arranged to have his *American Chemical Journal* combined with the *Journal of the American Chemical Society*.

"Remsen's Journal," as it was usually called by chemists, was started in 1879, as a matter of necessity, because there was no journal in America to handle research

papers in chemistry, and for several years he had been compelled to publish his articles in German journals. *The American Chemical Journal* became one of the recognized valuable chemical publications of all countries. During its entire existence it maintained a high standard. Dr. Remsen was very considerate in publishing contributions from his former students. He published several of mine relating to the chemical phases of cheese ripening. Gradually, the work ran more and more into practical application to cheese making. Finally, he sent a paper back, saying that its character was such that he felt that it did not belong in his journal and he had been in doubt about some of those he had already published. I wrote him, saying that while I regretted his decision, I appreciated his point of view and was grateful to him for having been previously so generous. At once, rather to my surprise, came back from him a gracious letter, in which he said that he wanted to thank me for the truly Christian spirit which I had shown in the situation. After telling me about the purpose of his journal and his trials as editor, he added that his life as editor would have been a much happier one if all who had had papers refused by him had shown the same spirit of sympathetic understanding I had shown instead of bitterly assailing him as a crank.

One of the most delightful personal contacts that the graduate students had with Remsen was in his daily visits in the advance laboratory, located next to his office. He stopped at each desk and talked with the student about the work under way. As I was several years older than the other students, being 30 (Remsen himself was then 43) and as I had had some teaching experience, he often talked with me about other topics than the laboratory work I was engaged in. On one occasion he told me how he came to write his first book on organic chemistry. After taking several courses of lectures in Germany, the subject was simply a chaos of a multitude of unrelated facts. He had a faint glimmering of insight, just enough to lead him to believe that somehow and somewhere there was some kind of a system, but for a time it was extremely vague. He groped and studied, largely in faith, for a long time. Finally, he began to see increasing glimmerings of light, and, gradually, true relations, previously only suspected, appeared. He realized that other students of organic chemistry must be in the same hazy state of mind that had been his. To help others and because there was no other book in the field, treating the subject in the same way, he published his book, *The Chemistry of the Carbon Compounds, An Introduction to the Study of Organic Chemistry*. Although I had had an extended course of lectures in organic chemistry in 1882, I never really knew the subject, until a few years later I read Remsen's book. His first book, *The Principles of Theoretical Chemistry, with Special Reference to the Constitution of Chemical Compounds*, was worked out by sheer force of persistent, personal, intellectual application, in order, primarily, that he himself might have a clear insight.

I will touch upon only one more incident. Among Remsen's students, in 1877-79, was a young German by the name of Constantine Fahlberg, who was working, under Remsen's direction, on the oxidation of ortho-toluene-sulfonamide. Fahlberg accidentally spilled on his working desk one day some of the compound with which he was working. In cleaning it up, he got a trace on his hands. Later, happening to bring his hand in contact with his lips, he discovered

that the substance was intensely sweet. Remsen demonstrated the structure of the compound and called it benzoic sulfinate. After leaving the University, Fahlberg made a personal commercial exploitation of the substance under the name of *Saccharin*, obtaining patents in the United States and abroad, without consulting Remsen. The production of *Saccharin* on an industrial scale was carried on by Fahlberg in Germany. This patenting and monopolistic commercialization of the results of some of his own work was a source of intense chagrin to Remsen, who was opposed, on principle, to the patenting, for private profit, of any result of university research work. I do not know that he ever made any statement for publication about the matter, but he spoke his mind freely to some of his students. What I heard about it came from student talk and was evidently handed down from previous years.

I will close this very imperfect sketch by saying that no earnest student could come in contact with Remsen without being profoundly influenced and helped. It was the most satisfying and profitable year I ever spent as a student. I learned a great deal of chemistry, but I gained even more outside of chemistry—I gained an intellectual stimulation and broadening, which, in the course of forty years, has not ceased to exercise a beneficial effect.

The last time I met Dr. Remsen was in 1907, when he gave the commencement address at the University of Michigan, at which time my son Donald was given his doctorate. Remsen's address was a memorable defense of science against the charge, which some unscientific, distinguished philosophers had been making, that science had become bankrupt. I was privileged to have a short chat with him after the address. He never failed to show a cordial interest in any one who had studied with him.

At the close of my year at Johns Hopkins, it was my hope to obtain a position to teach chemistry. Before a satisfactory position offered, I received an invitation from Dr. Peter Collier, director of the New York State Agricultural Experiment Station at Geneva, to visit the station with reference to considering the position of chemist there. When I received the invitation, I wondered what an agricultural experiment station might be—what it was for and what it was like. I investigated, saw that it offered an opportunity for real research work, was offered the place and accepted it. My previous agricultural education had consisted of the reading necessary for the preparation of the elementary articles on agricultural chemistry that I had written here for the *Planters' Monthly*.

I began my work at the Geneva station July 12, 1890. One month later I went to Washington to represent the station at the annual meeting of the Association of Official Agricultural Chemists, which was, I think, its ninth meeting. There I came into contact with Dr. Wiley again, only a few months after I had met him for the first time, when I had not the remotest idea of becoming an agricultural chemist. From that time on, I was in more or less intimate relations with him, especially through activity in the A. O. A. C., an organization with whose work you are all familiar. I know of no organization anywhere which has accomplished so much really substantial work for the promotion of agricultural chemistry as has the A. O. A. C. For the organization of the association, Dr. Wiley was primarily responsible. For forty years, his was the guiding hand and his the

directing mind that gave to the association consistent purpose and marvelous growth in usefulness. For most of that time he was the secretary and, in reality, the chief executive. Since 1912, Dr. Wiley has been the honorary president. He has never missed a meeting since the beginning of the organization.

A brief outline of Dr. Wiley's activities will be in order here. Born October 18, 1844, at Kent, Indiana, he graduated as A. B. at Hanover College in 1867. He taught Latin and Greek in Butler College, Indianapolis, for two years and science one year in the Indianapolis High School. Meanwhile he was studying medicine in the Indiana Medical College at Indianapolis and took the degree of M. D. in 1871. Deciding that he did not want to practice medicine, but did want to teach chemistry, he went to Harvard University for two years, getting the B. S. degree. He then became professor of chemistry first in Butler and then in Hanover College. He was a pioneer in America in the laboratory method of teaching chemistry. In 1874, Wiley was called to be professor of chemistry in Purdue University and the state chemist of Indiana.

In 1876, Dr. Wiley prepared the first college exhibit of chemical industry made in the United States. It was in connection with the Centennial Exhibition at Philadelphia. He had his students prepare 100 crystallized inorganic compounds. Organic chemistry was not represented, because it was just getting born in the United States under Remsen.

In 1883, Wiley was called to become chief chemist of the United States Department of Agriculture. When I first visited him in Washington in 1890, he had rather ordinary laboratory facilities and not many assistant chemists. In 1912, when he retired, the work had grown into a government bureau and employed over 300 chemists, covering many different lines of work, both routine and research. In addition to the force of chemists in Washington, there were several branch laboratories in different parts of the United States to assist in enforcing the Pure Food and Drug Law.

It is generally conceded that Dr. Wiley's greatest and most useful work was making possible the Pure Food and Drug Act, one of the most beneficent statutes on record, for to him more than any other one man was due its enactment and, during the initial period, its successful enforcement. Only those who had an intimate knowledge of the inside history preceding the enactment can appreciate the difficulties encountered. As one of Wiley's very minor associates, I saw something of these difficulties. In the passage of the law, the politicians were determined to have its enforcement placed in the hands of a political appointee, which would have endangered its success. Wiley was desirous that it should be placed in the hands of his department and, by some miracle, he succeeded in winning his point.

The fight was not finished even after the bill became law—in fact it was only begun. Manufacturers of food and drug products contested many cases bitterly in the courts, in order to modify in their favor some of the legal definitions that had been adopted for pure food and drug products. One of the best known of these disputes related to the use of preservatives, especially sodium benzoate and *Saccharin*. In order to prove his claim that these materials, as used, were injurious to the human body, Wiley undertook a series of experiments, in which he

tested physiologically the effects of these compounds on several vigorous young men, who became known as the "poison squad". The results of his experiments upheld his contention, but his methods were so vigorously criticized, that the president was persuaded to appoint a special commission to repeat Wiley's experiments. At the head of the commission was Ira Remsen. After many months of careful work, this commission reported that these preservatives were harmless when not used in excess of certain amounts. The commission, in carrying out its experiments, distributed the preservative uniformly through the mass of food eaten. Dr. Wiley, in his experiments, administered the preservatives in capsules. This method was criticized on the ground that, when the capsule dissolved in the stomach, its contents were set free in concentrated form and, before distribution could take place, acted directly on a portion of the stomach wall, producing the uncomfortable symptoms which Dr. Wiley found in his experiments, but which the commission did not find by its method of experiment, even when the same amount of preservative was used. Dr. Wiley's work was criticized also on the ground of using larger amounts in some of his experiments than were employed in commercial practice. Dr. Wiley never accepted the results of the commission's work, but the law was modified to permit certain amounts of certain preservatives. A further contention which Dr. Wiley put forward against the use of preservatives was that they were not needed at all, provided the materials were sound and sterilization complete, and the truth of his contention he established. If Dr. Wiley's zeal for public interest led him at first to advocate some standards that were more drastic than necessary, his purpose must be commended. His integrity was never under suspicion.

Each year at the meeting of the A. O. A. C., Dr. Wiley was called on to make an informal address on some topic of his own choosing—it was generally something particularly pertinent at the time. These talks were looked forward to as the most interesting feature of the meeting and they were never disappointing. He spoke without notes and, to all appearances, extemporaneously. The last time I heard him give one of these unique talks was in October, 1927, when he had just passed his 83d birthday. It was fully up to his high standard of former years. His mind was just as alert as ever, his expression as fluent, his logic as clear, his wit as keen; and the whole talk was as illuminating and stimulating and enjoyable as any he ever gave us. One of Dr. Wiley's attractive qualities is his wit, which is always bubbling over spontaneously. I recall an instance when the subject of starch determination was under discussion at one of the meetings of the A. O. A. C. One of the methods suggested was the digestion of starch by the use of saliva. Dr. Wiley remarked that the method gave excellent results, but that some objected to it on the ground that it was not "nice". He then added, "'Tis true, 'tis spitty, and 'spitty 'tis, 'tis true."

After his retirement, a banquet has been held in Dr. Wiley's honor each year during the meetings of the A. O. A. C. by the older members of the organization. I shall not forget the occasion of this kind when I was last present, a year and a half ago. These were occasions of intimate personal reminiscences, as we sat together. Dr. Wiley was at his best. For two hours he held our closest attention. He told us of some of his personal contacts with great men at home and abroad in

his inimitable way of thrilling interest. He talked of the development of chemistry in America and, finally, of the inner history of the enactment and enforcement of the Pure Food and Drug Law. At the close of this confidential family talk, I remarked to him that the facts which he had been telling us ought to be given a permanent record. He said he was working on an autobiography, which he hoped to finish before he was called from his labors. He said that he proposed to tell facts as they actually were and not as some had erroneously been led to believe. I can assure you that the book will be well worth reading. It will surely be informing. It will also certainly be the center of some stirring controversy.

It has been an interesting time to be a student of chemistry during the past fifty years. Much the greater part of the body of our chemical knowledge has been added during this period. The growth of chemical activity in America has been simply amazing—indeed, we can not fully comprehend it. Chemistry used to be studied in college as part of a liberal education and not enough was acquired to do any harm. Medical students were required to get a smattering, but not enough to do them any good. I knew a young medical student at Ann Arbor who said that he wanted to learn chemistry so that he could synthesize quinine. Most of those who took more than elementary inorganic chemistry intended to teach chemistry or become analytical or industrial chemists or pharmacists. A few under Remsen were beginning to get a vision of the possibilities of research. I do not remember ever to have heard the word research applied to chemical investigation, when I was a student. The expression then used was "original investigation".

The period of organic chemistry had then set in and continued to absorb most of the activity of American research students for years. Early in the nineties we began to hear of new developments abroad in physical chemistry and this field attracted an increasing amount of attention from Americans studying in Europe. Later it became very prominent in American research, especially in its applications to colloids. Since the beginning of the present century, interest has centered in ever-increasing intensity about biochemistry, which is, of course, simply the application of chemistry, whether inorganic, organic, or physical, to the study of living organisms and processes. With the passage of the Hatch Act by the Congress of the United States and the establishment of agricultural experiment stations in every state, there was a sudden unforeseen demand for chemists for research work. It is a marvel not that, in such an emergency, there were some poorly trained and inefficient men brought into the service, but that there were so many capable, strong men, among whom may be mentioned Atwater, Babcock, Hilgard, Caldwell, Armsby, Jordan, Jenkins, Voorhees, Kedzie, Woods, Scovell, and Stubbs.

The study of the applications of chemistry to every kind of agricultural problems, which we group under the head of agricultural chemistry, has grown with ever-increasing momentum during these fifty years. I do not need to go into details before such a group as this.

The most accurate measure of the activity of chemical research in America is the published literature. The first chemical journal in the United States was *The American Chemical Journal*, founded by Ira Remsen just fifty years ago. We

now have not less than ten journals devoted exclusively to chemistry and six or more, containing matter devoted, in part, to chemistry. A single one of these journals, the *Journal of Biological Chemistry*, published last year 4272 pages, which, of course, refers to a single annual copy. I presume that a conservative estimate of all the American journals would furnish an aggregate of more than 20,000 pages.

It would be interesting to know how many chemists there are today in America. Fifty years ago very few commercial chemists were employed, and these mostly in steel-making plants, a few of the largest drug and chemical supply houses and, perhaps, an occasional one in some other line. To attempt to recapitulate the variety and number of different kinds of chemists in America is a task I will leave to some one who has more years ahead of him than has the speaker.

Finally, imagine, if you can, the state of mind in which any leading chemist of fifty years ago, who had passed away then, would be, if he were able to come to life now. Let him try to read an up-to-date elementary text-book of chemistry. He would find names of elements that did not belong there. He would be able to recognize scarcely any of the chemical formulas of compounds, organic or inorganic, and certainly not a single one of the structural formulas. He might wonder if s-u-l-f-u-r is one of the new elements. The atom, which in his day was a simple, indivisible particle, he would utterly fail to recognize in the one-to-several ringed circus of the present. Such words as ions, electrons, colloids, gels, adsorption, electrolytic dissociation, hydrogen ion concentration, radio activity and thousands of others would be absolutely meaningless to him. The symbol pH and many others which sprinkle the pages of chemical literature so generously today would have as much meaning to him as to an infant. Practically all of the terms used in biochemistry would signify nothing. All of the chemistry of the proteins would be wholly unintelligible. And so we might go on *ad infinitum*, *ad nauseam*. After hours or days of increasing, mystifying bewilderment, we can imagine him shaking his dizzy head, throwing up his hands in utter despair and vaporizing.

Sugar Prices

96° Centrifugals for the Period
March 19, 1929, to June 15, 1929.

| Date | Per Pound | Per Ton | Remarks |
|---------------------|-----------|---------|---------------------------------------|
| March 19, 1929..... | 3.71¢ | \$74.20 | Cubas. |
| “ 22..... | 3.695 | 73.90 | Cubas, 3.71; Philippines, 3.68. |
| “ 25..... | 3.67 | 73.40 | Porto Ricos. |
| “ 26..... | 3.64 | 72.80 | Philippines. |
| April 3..... | 3.595 | 71.90 | Cubas, 3.61; Porto Ricos, 3.58. |
| “ 5..... | 3.55 | 71.00 | Porto Ricos. |
| “ 8..... | 3.565 | 71.30 | Porto Ricos, 3.55, 3.58. |
| “ 9..... | 3.625 | 72.50 | Porto Ricos, 3.61, 3.64. |
| “ 10..... | 3.64 | 72.80 | Porto Ricos. |
| “ 11..... | 3.69 | 73.80 | Philippines, 3.67; Cubas, 3.71. |
| “ 12..... | 3.71 | 74.20 | Cubas. |
| “ 15..... | 3.74 | 74.80 | Porto Ricos. |
| “ 16..... | 3.69 | 73.80 | Cubas, 3.71; Philippines, 3.67. |
| “ 18..... | 3.625 | 72.50 | Philippines, 3.61; Cubas, 3.64. |
| “ 19..... | 3.61 | 72.20 | Philippines. |
| “ 25..... | 3.71 | 74.20 | Cubas. |
| “ 26..... | 3.68 | 73.60 | Cubas. |
| “ 30..... | 3.58 | 71.60 | Porto Ricos. |
| May 3..... | 3.64 | 72.80 | Porto Ricos. |
| “ 6..... | 3.595 | 71.90 | Porto Ricos, 3.61; Cubas, 3.58. |
| “ 8..... | 3.58 | 71.60 | Philippines. |
| “ 9..... | 3.565 | 71.30 | Porto Ricos, 3.58, 3.55. |
| “ 10..... | 3.565 | 71.30 | Porto Ricos, 3.58; Cubas, 3.55. |
| “ 11..... | 3.58 | 71.60 | Cubas. |
| “ 14..... | 3.595 | 71.90 | Philippines, 3.58; Cubas, 3.61. |
| “ 15..... | 3.595 | 71.90 | Cubas, 3.61; Porto Ricos, 3.58. |
| “ 16..... | 3.58 | 71.60 | Cubas. |
| “ 17..... | 3.595 | 71.90 | Porto Ricos, 3.58; Cubas, 3.61. |
| “ 18..... | 3.61 | 72.20 | Cubas. |
| “ 20..... | 3.596 | 71.93 | Porto Ricos, 3.58; Cubas, 3.61, 3.60. |
| “ 21..... | 3.58 | 71.60 | Porto Ricos. |
| “ 22..... | 3.55 | 71.00 | Philippines. |
| “ 24..... | 3.58 | 71.60 | Cubas. |
| “ 28..... | 3.565 | 71.30 | Cubas, 3.55, 3.58. |
| “ 29..... | 3.535 | 70.70 | Cubas, 3.55; Porto Ricos, 3.52. |
| June 3..... | 3.49 | 69.80 | Porto Ricos. |
| “ 5..... | 3.46 | 69.20 | Philippines. |
| “ 11..... | 3.465 | 69.30 | Cubas, 3.47, 3.46. |
| “ 12..... | 3.46 | 69.20 | Cubas. |
| “ 13..... | 3.49 | 69.80 | Philippines. |
